HIGHWAY RESEARCH RECORD

Number 394

Transportation Systems Planning Process

4 reports

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FOREWORD

In the transportation systems planning process, greater consideration is now being given to the process itself. With the great concern for ecological and environmental issues, with citizens' groups demanding participation in the total location and design process, and with broadening legislation to protect against adverse effects of transportation systems, the transportation planning process—even though it is one of the more advanced public planning processes—is coming under critical reappraisal. In this RECORD, four papers are presented on the transportation systems planning process.

Reno discusses the legal and political interaction requirements among agencies, public officials, and private groups that are necessary throughout the entire planning process. He points out that all participants in the process should feel their interests are adequately represented at every stage in the process.

Selecting and scheduling projects for construction is a continuing problem. Miller discusses the scheduling of highway improvements. He contends that the optimum time for construction is at the point when annual benefits minus maintenance costs first exceed the product of the discount rate and the capital cost of the project.

Boyce, Farhi, and McDonald discuss in their paper the characteristics of a new plan-making process and identify methods for designing plan-making procedures for use in such a process. The paper includes an example and a point-by-point statement of the plan-making procedure recommended.

In evaluating alternative transportation systems it is necessary to develop a procedure that will relate the transportation system to the environment through which it passes. Sharpe and Maxman present a method for quantifying and evaluating the environmental effects of transportation improvements. An annoyance index of people's perception of noise, air pollution, and safety according to traffic volume was developed. An "environmental capacity" defined in terms of vehicles per day was established for each roadway segment in the study area.

INTERACTION PROCEDURES IN THE TRANSPORTATION SYSTEMS PLANNING PROCESS

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There are legal and political requirements for extensive interaction in transportation planning. Interaction among agencies, public officials, and private groups should take place throughout the entire system planning process, not just at the project planning level. The procedures through which the interaction takes place are as important to a process as the organizational structure and the division of responsibilities. The desirable characteristics of interaction procedures are that all participants should feel their interests are adequately represented at every stage in the process, that informal as well as formal ties should be developed, and that each participant should make the choice as to how deeply involved he wishes to be. Reporting and review procedures can be changed so that they are more process-oriented as opposed to product-oriented. The time-consuming reporting of details can be curtailed and streamlined. Process review procedures can stimulate operating levels to be more issue-oriented.

•THERE IS an emerging recognition among transportation planners that the process through which decisions are made is a critical aspect of system planning and that solutions to many present problems can come only through sensitive design of a decision-making process rather than through the creation of better technical tools or through organizational changes.

Transportation planning affects many interest groups who are concerned about decisions. This is true at the project level—that of planning a new freeway or transit route in an urban area—but it is even more true at the system level, in which many projects staged over time are being contemplated for a metropolitan region. If interaction among a transportation agency, local public officials, and private groups occurs only at the project level, when significant options may have already been eliminated, its effectiveness is limited severely. Therefore, there should be possibilities for effective participation of public officials and citizens at each stage in the transportation planning process. If the process is not open, responsive, and credible at all stages, it is not open, responsive, and credible at all.

Two important questions in transportation systems planning are

1. What are the important elements of a good decision-making process in transportation system planning?
2. How can good interactive processes be encouraged and measured?

Much effort has been expended on each of these questions, and no single new paper ever provides more than a small part of the answers. For instance, changes in attitude in the profession may be critical to operating successfully in the future legal and political environment. Attitudinal changes are long-term and depend on training and experience. This paper does not discuss attitudinal changes and touches only briefly on organizational structure. This paper is divided into four sections. The first two describe the legal and political framework within which interaction occurs among transportation agencies, public officials, and private groups. The last two sections provide suggestions for improvements in the systems planning process.

Sponsored by Committee on Social, Economic and Environmental Factors of Transportation.

It should be noted that the implications of many suggestions here are far-reaching and have not been tested in practice. This paper is thus partly a reporting of research results and partly tentative recommendations that are extrapolations from the research.

LEGAL REQUIREMENTS FOR INTERACTION

Extensive interaction in transportation planning is required by federal laws and guidelines and by state laws and guidelines. The 1968 Federal-Aid Highway Act amended Section 128 of Title 23 United States Code such that

> Any state highway department which submits plans for a Federal-aid highway project involving the bypassing of, or going through, any city, town, or village, either incorporated or unincorporated, shall certify to the Secretary that it has had public hearings, or has afforded the opportunity for such hearings, and has considered the economic and social effects of such a location, its impact on the environment, and its consistency with the goals and objectives of such urban planning as has been promulgated by the community . . . .

Policy and Procedure Memorandum 20-8, "Public Hearings and Location Approval," implements the 1968 Federal-Aid Highway Act and shows the clear intent of the Federal Highway Administration to require a process involving effective public participation in all phases of a planning process. PPM 20-8 states that

> The rules, policies, and procedures established by this PPM are intended to afford full opportunity for effective public participation in the consideration of highway location and design proposals by highway departments before submission to the Federal Highway Administration for approval. They provide a medium for free and open discussion and are designed to encourage early and amicable resolution of controversial issues that may arise.

The Intergovernmental Cooperation Act of 1968 and Bureau of the Budget Circular A-95 are intended to ensure that "all viewpoints ... national, state, regional, and local ... shall to the extent possible be taken into account in planning Federal or federally assisted development programs and projects." Applications for federal assistance on highway projects are subject to review according to Bureau of the Budget Circular A-95 and thus must be accompanied by the comments of an area-wide comprehensive planning agency as to the relationship of the proposed project to the planned development of the area.

The National Environmental Policy Act of 1969, Section 102(2)(c), says that

> all agencies of the federal government shall include in every recommendation or report on proposals for legislation or other major federal actions significantly affecting the quality of the human environment, a detailed statement by the responsible official on
>
> (i) the environmental impact of the proposed action,
> (ii) any adverse environmental effects which cannot be avoided should the proposal be implemented,
> (iii) alternatives to the proposed action,
> (iv) the relationship between local short-term uses of man's environment and the maintenance and enchancement of long-term productivity, and
> (v) any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented.

Executive Order 11514, "Protection and Enhancement of Environmental Quality," Section 2(b), directs federal agencies to

> . . . develop procedures to ensure the fullest practicable provisions of timely public information and understanding of federal plans and programs in order to obtain the views of interested parties. These procedures shall include whenever appropriate, provisions for public hearings, and shall provide the public with relevant information, including information on alternative courses of action. Federal agencies shall also encourage state and local agencies to adopt similar procedures for informing the public concerning their activities affecting the quality of the environment.

The Federal-Aid Highway Act of 1962 requires a "continuing comprehensive transportation planning process carried on cooperatively by States and local communities..." in all urban areas of more than 50,000 population. Policy and Procedure Memorandum 50-9 says, "The planning process should be closely coordinated with policy making and program administration and should be organized with the objective of achieving agreement on interrelated action programs founded on factual information."

The Federal-Aid Highway Act of 1970, Section 136(b), provides that

> Not later than July 1, 1972, the Secretary, after consultation with appropriate Federal and State officials, shall submit to Congress, and not later than 90 days after such submission, promulgate guidelines designed to assure that possible adverse economic, social and evironmental effects relating to any proposed project on any Federal-aid system have been fully considered in developing such project, and that the final decisions on the project are made in the best overall public interest . . . .

The 1970 Act implies that such factors should be considered throughout the whole planning process, since project alternatives are certainly being developed at early stages. The definition of a transportation system through designation of a freeway network is certainly an activity through which projects are developed. Most of the cited laws require or imply extensive interaction but are geared toward project-level impacts, and further consideration of explicit legal language intended to specify interaction through an entire process may be desirable, but only if it is flexible enough to allow for a dynamic, phased decision process.

POLITICAL AND PSYCHOLOGICAL REQUIREMENTS

Trends in the development of institutional structures and the power relationships within those structures point to a need for an interactive process. The developing situation seems to be one in which an effective veto power over transportation projects will exist at many levels of government. States have always had an effective veto power over highway programs because state agencies are the usual implementing authorities and because cities, counties, special districts, and commissions are creatures of the state. Local jurisdictions in some states (such as California) have had effective legal power to veto highway projects in their areas. In some other states, cities do not have the formal legal authority to veto projects but have shown that they do have the political power necessary to block projects.

The level of "government" that has had no politically effective veto power over projects is the metropolitan area. Metropolitan agencies have had some legal power over projects, since they are required to comment on them, but their lack of political power has kept them from effectively exercising even the legal authority they hold. This situation seems likely to change and will most likely come about in response to environmental concerns. Regional institutions or perhaps even private groups seem likely to acquire the teeth necessary to block projects they judge undesirable. This is coming about largely because critics of projects are organizing to prevent "divide and conquer" tactics from being effective. This has been the case in most successful "freeway revolts," such as in San Francisco, where neighborhood associations banded together to influence the city's Board of Supervisors to take an anti-freeway stand, or in the Boston metropolitan region, where a broad anti-highway coalition, The Greater Boston Committee on the Transportation Crisis, was formed and has pushed successfully for a redirection in transportation planning in that metropolitan area. It is also conceivable, and even likely, that in some states, metropolitan groups of legislators will effectively block transportation plans for their regions if they are dissatisfied with the process.

The power to implement does not exist everywhere that the power to veto does, and the power to implement (for metropolitan institutions) should be judged now as less likely than the trend toward veto at every level. More substantial organizational changes are required if the metropolitan agency is to develop a capability to propose and finance solutions to metropolitan transportation problems than are required if the metropolitan institution is simply to have a politically effective veto over other's (e. g., state agency's) plans.

When veto power exists for many institutions, a bargaining process must be instituted if there is ever to be any action besides "doing nothing." The various institutions and their constituencies will have to negotiate in order to reach agreement on a course of action, and this negotiation will involve compromises on the part of all participants.

All governmental programs are ultimately responsible to the public, both directly and through elected officials, and all governmental programs must be responsive to that public. Despite a widespread myth, there is no evidence that today the American public is more willing than before to accept decisions made "technocratically" or by "experts who know better." In fact, most evidence seems to point to a growing reluctance to accept technocratic decisions, particularly in projects that directly affect local communities.

In a political sense, interaction at the system planning level is necessary so that local officials become aware of the impacts of their positions and decisions on other areas and so that they may have a forum for bargaining and negotiating over issues. Although one does not expect, and it is not necessarily desirable, that all local officials adopt a "regional view," an awareness of the consequences perceived by others, and of other's positions and strategies, can go a long way toward making system planning more responsive. Because the local officials often have effective veto power over projects affecting themselves, they must be intimately involved in a system-level bargaining process.

When outcomes are uncertain, and where system planning affects many groups in many different ways, there are no legitimate criteria for judging among many system plans. How can one judge whether having a bit more transportation investment in a region is or is not worth a bit less open space or neighborhood amenity, or investment in housing, or other public services? These are not technocratic decisions; they are decisions that must be made through a democratic decision-making process in which the interests of all groups are represented.

A related set of requirements for interaction results from the psychological needs of persons to be involved in decisions affecting their interests. The same sorts of psychological needs are exhibited by persons both inside and outside a transportation agency. Individuals may feel a need for various levels of influence. A person might feel that an agency's obligation to him should be

1. To inform him of the broad outlines of what is going on;
2. To consult him for his opinion on issues; and
3. To ask him for approval.

A large change is taking place in the demand for satisfaction of the first and second psychic needs—those of involvement—by both local officials and the general public. A smaller number of groups of local officials and citizens wish to feel they have power of approval over actions affecting them—the third psychic need. Such levels of influence are not entirely parallel to intensity or degree of involvement. Interest in decisions and power over them are not the same. A process can be either psychologically rewarding, neutral, or psychologically insulting. It is largely the procedures of interaction that may or may not result in psychological satisfaction. Only a broad and open process can provide psychic satisfaction to a wide range of interested people.

However, a new process of interaction not only has to serve the psychological needs of the public but also must be grafted onto a present process that has created patterns of psychological desires that may be in conflict with change. For some people, there are psychic costs to changing plans and procedures.

If someone has invested many years in developing and implementing a particular transportation system, he may be quite defensive about criticism of that system. Likewise, even though all professionals should search actively for ways to do a better job, they are sometimes reluctant to admit publicly the shortcomings of their own past practices. The admission of past shortcomings leads directly to the need for recycling past work, a sometimes distressing burden. Thus, one is not surprised to find that changes in policy are often accompanied by changes in personnel or by changes in status and power within the organization. These observations also point up the need to avoid forcing people to make psychological commitments too early in a decision process. One

of the prime faults of the "master plan" approach is that so many people are asked to be committed to a plan whose consequences no one knows. The psychological costs of changing the "master plan" may then be substantial, even though there are no "rational" reasons for being committed to an outmoded plan.

Engineers as a professional group traditionally have not been trained to be comfortable with uncertainty and unknown situations. It may be psychologically harder to face unknown situations, such as community interactions over system and project plans, than the familiar, such as engineering details.

There are also psychological problems involved with facing criticism of one's own work. Planning and design involve someone's ego, just as any other creative activity does. Presentations to others are likely to become self-serving or defensive if agency personnel allow their egos to become too involved with their work.

This leads to a conclusion that there are psychological qualifications necessary for agency personnel to be able to run an open process well. They must be comfortable with uncertainty and capable of accepting unknown situations. They also must be willing to control defensive or angry reactions to criticism. In system planning, much more is unknown to the planner, and he must be willing to admit to a more substantial lack of knowledge during interaction with the public. Thus, there is some conflict between the psychological needs of candid interaction on the public's part and the psychological needs of some planners to appear to have all the answers. The resolution to this problem lies not in stifling the creativity of the planner but in channeling his need to be creative toward solving problems perceived by the public. An open process calls for interaction procedures that capitalize on the psychological needs of various participants rather than procedures that assume an ideal rational man.

RESPONSIVE AND RESPONSIBLE INTERACTION PROCEDURES

We cannot now reasonably judge what the best system plan for a region will be 25 years hence, nor are we even likely to formulate a plan with a reasonable likelihood of occurrence. But we can specify some aspects of a desirable process of choice over time, so that we may feel the process provides a reasonable chance for an equitable balancing between groups and a reasonable integration of immediate concerns with longer range goals.

Some basic characteristics of a pragmatic interaction process are the following:

1. Interaction must occur among all agencies, offices, groups, and individuals in planning and with all the interest groups affected by decisions. Two kinds of integration are necessary. One is information, which must flow between the various individuals and groups involved. The other is personal interaction, which is indispensable to the development of an understanding of each other's concerns and points of view. Many issues simply have to be talked out in small meetings so that each party gains an understanding of the real concerns of others.

2. As a general rule, it is desirable not to exclude anyone from interaction. Each participant and interest group must feel that they are represented in all decision forums. The process of communication between the various agencies, offices, and participants, particularly the communication of intangibles such as trust, is critical. The more participants and decision-makers there are, the more difficult it will be for each participant and decision-maker to be involved in all decisions affecting them. But if persons are to be truly committed to a decision, they should be involved in the process. This is the only way to counteract the development of a "we versus they" attitude.

3. Local officials and private groups themselves should be the ones who choose how deeply they will be involved. A mass democratic process in which everyone always participates is likely to be unworkable, so most groups will have to be represented by either formal or informal spokesmen. To keep most meetings manageable, groups with similar interests should be asked to band together and choose a common spokesman.

4. In general, small meetings are more desirable than large public hearings or mass meetings, which essentially serve for political posturing. A numbers game of witnesses for and against particular ideas is not desirable. The public hearings should really serve as checkpoints on whether issues have yet been resolved.

5. There are three different degrees of involvement at which citizens and local officials might wish to participate. These are (a) awareness of the process that is going on, through either the public media, or a newsletter, or conversation with acquaintances, and the expression of their concerns to someone else; (b) periodic attendance at public meetings to monitor what has gone on, and to flag issues of concern; and (c) intensive involvement and review of the specific details of the agency's or the consultant's work. The agency should make involvement possible at all these levels by providing for a wide range of interactions. Also, background materials should be continually updated, so that someone who attends a meeting for the first time can inform himself on the present state of the process.

6. One problem is that of motivating someone to deal with decisions some of whose consequences may be far removed, perhaps 30 or 40 years in the future. Even for the professionals involved, decisions about such a time horizon seem slightly unreal, and well they might, because any long-term actions are sure to be reviewed and studied in much more depth before they are implemented. Another important aspect of the decision process must be that there are sufficient short-range decisions to be made to motivate people to participate. Yet the long-range consequences, if any, of those immediate decisions have to be pointed out, and groups potentially affected only by the long-range consequences need information about what is being considered at present.

7. Ad hoc forums for compromise and negotiation are necessary in transportation so that those making decisions may be adequately informed of the issues involved. It is too much to ask general governments to deliberate all issues—especially where, as in corridor issues, the groups affected will not be constant but will depend on corridor definition. The ad hoc interaction efforts of many officials and agencies concerned with transportation planning should be known to each other and should be integrated. This does not imply that a public relations office should be responsible for all interaction with the general public. Rather, it means that the activities of each group doing interaction should be known to each other group. No one office should have the responsibility for community interaction, because every office needs to engage in at least some community interaction.

8. The process through which minority rights are safeguarded should operate at each point in the process. The city can obviously prevent the state from causing negative impacts to itself (presumably for the better good of the citizens of the state). State and federal review procedures can also operate to monitor whether local governments are treating all their residents fairly. Hypothetically, some groups—the elderly, the handicapped, etc.—may not be well represented at the city level but may conceivably be able to bring effective influence to bear at the state or federal levels, where it is possible for them to band together with many others from different regions.

9. Formal reporting procedures are required between offices and agencies. It is dangerous to rely totally on informal structure or informal communication in large system planning activities. Each office should have an explicit communication strategy.

10. Not everything can be written down in a process and communicated to other agencies in that form. Much that cannot be written down easily is the kind of information on which the "success" of a planning process depends if success is to be measured by whether substantial agreement has been reached. This information includes such things as impressions of a group's attachment to a particular concern or whether or not two groups might be willing to negotiate an equitable compromise on their respective points of view. These probabilistic kinds of impressions do not lend themselves well to formalization into documents. People do not like to have forecasts made of their future actions, and publicizing the possibilities for switches in position may in fact jeopardize the chances that they will occur.

11. A "web of trust" is one possibility for structuring the relationships among levels by creating interlocking groups. This emerged from the beginning phases of the Boston Transportation Planning Review, a multimodal and participatory system planning effort reporting to the Secretary of Transportation and Construction and the Governor of Massachusetts. The Boston Transportation Planning Review is an advisory group to the Secretary of Transportation and the Governor, and the participants are made up of

representatives of state agencies, municipal officials, legislators, private groups and associations, and professional societies. One important aspect of the Boston Transportation Planning Review was that setting up the structure and interaction procedures in the system planning process was done through the participatory interaction process itself. Private groups and even municipalities were encouraged to band together when their interests coincided and agree on spokesmen to represent them at meetings. The planning review was structured to have an overall steering group, and advisory body on urban transportation system planning in the metropolitan region, and subarea or corridor committees to look more intensively at projects and groups of projects in particular areas. Consultants were hired, again with the participatory process providing advice to the state agencies, and consultant personnel serve as staff for the process as a whole. The region-wide steering group and the subarea committees have overlapping memberships. This greatly facilitates communication among these levels and also, of course, serves to provide a "web of trust," in that those who serve on other levels are known to the membership of each committee and the representatives are chosen by the participating groups themselves. This does not imply that everyone in the process will trust or agree with everyone else in the process but only that they trust someone to be representing their interests at each meeting.

12. The transportation agency personnel or consultants should act as staff to local officials in helping to develop the information on which those local officials must make a decision. The transportation agency should perform this role for pragmatic reasons: The local public officials probably have a limited staff, with limited expertise in some of the necessary professional areas. The ideal case would be a true partnership, where through cooperative agreement each would contribute staff, and agency and local staff would work hand in hand to run interaction processes.

13. Procedures for interaction cannot be elitist or self-serving but must serve the process of decision-making. We have witnessed that the typical presentations of highway agencies or consultants are not "process-serving" but rather self-serving. The "message" of the presentation to the public is usually "we have been doing a good job" or "look at how much the experts understand about the problem and all these charts we have to back up our conclusions." This frustrates the participants, for the public is not at all interested in such a message. People are dissatisfied with self-serving presentations. Process-serving presentations may not initially serve the ego needs of consultants or agencies inexperienced in community interaction, because the intent of the presentation is not to impress. People in front of a crowd want to feel they are impressing others and want to seem to have more answers than they do. Also, besides defensiveness to criticism, the agency personnel or consultants may disagree completely with the criticisms expressed. A response of rage, sarcasm, or ridicule is not process-serving, because it leads to polarization between participants and planners. Also, such a response is only ego-serving in the short run, because in the long run satisfaction will come from the success of the process.

ENCOURAGING RESPONSIVENESS THROUGH HIGHER LEVEL REVIEW: PROCESS REVIEW VERSUS PROJECT REVIEW

Review can look at two sorts of things: It can deal with projects or products, and it can deal with process. Most reviews today are project reviews—reviews of a particular alternative and its impacts at the level of detail to which work has progressed. Basic Design Report reviews; Plans, Specifications, and Estimates reviews; 4f Statements; and Environmental Impact Statements are all reviews of a proposed project.

To some extent, project review procedures do not reflect the kind of process necessary to achieve good decisions in accordance with basic democratic principles. Some review of both types is certainly necessary, but where they are in conflict, there would seem to have to be extraordinary circumstances for project reviews to have more importance than the overall process.

At present, higher levels seem to measure "progress" at lower levels through the percentage of completion of some current plan and by the lower levels' percentage completion of the detailed work activities that precede implementation for each project.

It is not desirable that project details never be submitted to higher levels for review. However, it is probably true that too much staff time at each level is spent in the transmission and receipt of details on projects. But, much worse, this hierarchical review of project details probably tends to make it more difficult to change anything, since so many approvals for changes have to be forthcoming from so many levels. Instead of a dynamic, flexible search for alternatives, one acquires a calcified bureaucratic plodding, in which each level, office, or agency shies away from changing anything about an initial alternative because of the difficulties in getting the change through all the necessary channels. So, it is probably desirable that much less be done to monitor the project at each level, or that approvals of detail not be formal. This is especially true for small or minor projects, but it applies to large projects also.

However, it is also desirable that more be done to monitor the process as a way for higher level management to provide incentives for incorporating community and environmental values in every stage. If a desirable process is specified, there is no longer a need for project reviews in detail.

The two public hearing requirements of PPM 20-8 can be seen as a tentative first step toward a process review procedure. Unfortunately, the two-hearing requirement is pasted into a whole set of project review procedures. One hearing is called a "location" hearing and the other a "design" hearing, so this process is also oriented to level of detail. The two-hearing procedure has been controversial, and many operating agency personnel have looked on it as another burden of reporting. Tacked onto other approval requirements and present reviews, it is not accomplishing its original purpose very effectively. Rather, the requirement for two hearings should be looked at as indicating that interaction and agreement must be sought throughout the process. The two-hearing requirement is the first step toward getting a fully interactive process. What is important are those aspects of the process that occur outside the public hearings, which are only two points in time and do not provide a sufficient forum for discussion and negotiation but only for monitoring issues and positions. The next steps must be taken by operating agencies themselves, and they must also convince FHWA to change any review procedures that inhibit dynamism in a decision process.

To be responsive to the public, reporting procedures should be streamlined at the same time that they are being changed to be more reflective of community and environmental values. In this respect, the interests of the public and the transportation professional are the same. The formalized red tape and step-by-step bureaucratic procedures can be cut down. In their place, simpler and more relevant information could be reported.

Process monitoring is not easy, and any reporting procedures are bound to be inadequate as a representation of what has occurred and why. Records of public hearings provide a register of reactions and complaints about the process as well as of reactions about proposed alternatives, yet it is rather hard to distinguish whether someone might be dissatisfied over the conduct of the process or over the possible outcome. Also, any lack of protest about a process might not indicate that a "good" process has been followed. Persons may feel that protest is futile, may never have known they have a right to speak out, may feel uncomfortable criticizing public agencies, or may dislike the process but agree with the outcome. Thus, a lack of controversy may not indicate a comprehensive process in which all impacts on different groups were considered fairly. Despite these difficulties, some process review is meaningful, but that review information should be easy to compile and report. The ideal would be a shorthand method of reporting just where the process stood in terms of its progress toward decision. While probably no ideal will be found, the most meaningful measures are likely to be people's positions and concerns over the issues yet to be resolved.

In any process, the most important information is always people's positions on various issues, particularly the positions of superiors in the agency or of public officials with authority over actions. This information is what defines the priorities for the process at any point in time as well as its chances of success.

Perhaps a helpful formal document to transmit between levels is the kind of periodic evaluation summary described in M.I.T.'s work on project planning. The periodic evaluation summary consists of six steps:

1. Review and summarize the input to evaluation;
2. View the process from the viewpoint of each affected interest;
3. Identify potential areas of conflict and agreement;
4. Identify issues of feasibility and desirability for each alternative;
5. Assess the potential of each alternative; and
6. Identify priorities for development of alternatives, impact prediction, and community interaction.

These six steps only indicate the type of information that it may be valuable to report between levels. An example evaluation summary is presented in the M.I.T. Procedural Guide.

By monitoring the concerns of people, one is able to get some understanding of the very important intangibles such as trust and credibility that must be communicated at and among all agencies and participants—things that are of utmost importance for the success of the project, yet do not get communicated in formal reports from one level to another.

At each higher level, the decision-makers involved are likely to be somewhat more removed from the important concerns of individuals and groups, particularly because many such concerns and their intensity only become apparent when one is face to face. This suggests that personal interactions should occur among many levels of decision-making, so that decision-makers who are further removed from the intimate knowledge of particular problems of their subtleties become exposed. Trust is probably impossible to communicate without personal contact. Process review procedures should thus be structured to elicit how levels are related through the persons who participate at each level.

It is important to reconcile the needs of both the professionals and the public. The professionals involved want to have their work accepted by their superiors and by the public. Like most other groups of workers, they do not want to assume the burden of what seem to them to be nonessential work tasks. Much report writing seems to be nonessential today to the engineers and planners doing the work, and this includes environmental reports.

To some extent, the attitude that there is too much red tape is justified. Planning and design personnel feel they are devoting most of their lives to reporting each of their activities to their own agency and to a multitude of other agencies. However, some of this reporting is necessary for coordination among highway programs, public officials, the public, and other planning agencies, and for accounting purposes to provide checks on the expenditures of public funds.

No one can promise a transportation professional that running a participatory process, in which technical activities and basic democratic principles are closely intertwined, is going to involve less work. The time demands of interaction are substantial. They already are, and broadening the interactive process is going to mean even more time-consuming work. However, a great deal of time is also consumed if projects, designs, or programs are rejected by those who have not been involved and the process has to start all over again. An interactive process geared to getting effective agreement the first time through is the type of process most likely to serve the interests of all groups involved.

The public has a need to know and a need to be involved. The transportation agency must be responsive to outside suggestions, for both pragmatic and democratic reasons. The pragmatic reason is that people are likely to oppose things they do not understand and have had no influence in shaping. The democratic reason is that it is the right thing to do. Process review can stimulate operating levels to be more responsive to the public. At the same time, the interests of professionals can be served by removing from them the burden of reporting many details, which becomes a hindrance to a dynamic process because all changes have to be approved by higher levels. It is in the interest of both the public and the transportation professional to replace detailed review procedures with process review procedures.

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SCHEDULING OF HIGHWAY IMPROVEMENTS

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Although a showing that benefits exceed costs indicates that a project should be constructed sometime, it does not necessarily indicate that the optimum time for construction is now. Likewise, the highest priority projects are not necessarily those with the highest benefit-cost ratios or the highest internal rates of return. Instead, for most highway projects the optimum time of construction is when annual benefits minus maintenance costs first exceed the product of the discount rate and the capital cost of the project. If funds are not available to build all desired projects now, the projects to be built first should be selected in order of their priority ratio. In the simplest case the priority ratio is the first-year benefits minus maintenance and operating costs, divided by the capital cost of the project. Given the usual situation of steadily increasing benefits, highway improvement projects are relatively risk-free investments.

•THE GOAL of highway planning and scheduling is to select a program of projects for which the present value of benefits minus costs is at a maximum, subject to any relevant annual budget constraints. The constrained budget problem discussed here differs from the usual formulation in which there is a fixed total amount to be spent at once. [For a discussion of the traditional problem of obtaining maximum total benefits from a total fixed amount to be spent at once see Hirshleifer, DeHaven, and Milliman (1).] This is considered a more realistic formulation because, for capital investment programs of any magnitude, it is not possible to meet all needs within a single year. Even if the legislature would appropriate the required funds, limitations on resource availability and planning capabilities would make it impossible to expend all of the funds in a short period of time. Certainly, it is unrealistic to plan for simultaneous construction of all needed highways. In the discussion here, highway projects will be considered to be independent of each other, although it is realized that this assumption is also often unrealistic. It will also be assumed that all projects have already been examined for economic feasibility and found to have benefits that exceed costs on a present value basis. [For a discussion of how to calculate benefits see publications by AASHO (2) and Winfrey (3).]

PROJECT TIMING IN THE ABSENCE OF A BUDGET CONSTRAINT

It is sometimes asserted that a project should be built now if its discounted benefits exceed its discounted costs. This is incorrect; such a test only shows that a project should be built sometime.[1]

This can be shown by a simple example. Consider a new town that is scheduled to be built 5 years from now. Building the road leading to it will cost \$1,000,000 and produce benefits of \$1,000,000 per year once it is open. Suppose we are using a 10 percent discount rate. The present value of benefits is \$6,100,000 for a benefit-cost ratio of 6.1. Such a road is clearly worth building and would probably have a high priority in

[1] Similar conclusions to those drawn here have been reached by Margolin (4, 5); also see Arrow (6). For a highly mathematical discussion of the problem of transportation project scheduling that comes to some of the same conclusions expressed here see Beenhakker (7).

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any list of projects ranked by benefit-cost ratios. Yet it would clearly be a mistake to build the project now, giving it priority over roads that are already needed. If built now, the road would sit idle for 5 years before being used. Obviously the correct time to build the road is just before the new town is constructed when the road is needed.

In this extreme case, the error in relying solely on the benefit-cost ratio is clear. A more realistic case is obtained if, instead of an entirely new town, we use one that is expected to grow very rapidly. A traditional benefit-cost ratio calculation may give a high ratio because of the large volume of traffic that the road will carry in the future. Yet it would be a mistake to give the road high priority now, because the amount of traffic that would use the road initially would be small and unable to justify immediate construction of the road. [An example of an otherwise good study that fails to take this into account is Hejal's economic priority model (8).] The remainder of this paper will discuss the problem of when to build a project that is justified and how to assign a priority to such projects.

The optimum time for building a project is the time when, with all costs and benefits discounted to the present, the excess of benefits over costs is at a maximum. Only in special circumstances will the discounted value for net benefits (benefits minus costs) pass through a maximum at the exact point where benefits are equal to costs. In all other cases construction of a justified project as soon as discounted net benefits are positive will lead to premature construction of the project.

Let us start the discussion by considering a case in which the cost of building a road between two growing cities does not vary with when the road is built. However, the traffic on the road will grow over time with growth of the cities. For simplicity assume that the highway does not influence the location of population and that the traffic carried by the highway varies only with the calendar year, not the year in which the highway was constructed. The proposed design for the highway will have a high enough capacity so that it will be able to handle many years of future growth in traffic without serious congestion. Thus benefits will grow continuously at the same rate as traffic. This is a simplified model of the situation applicable to most rural roads and many rural Interstates.

Let us consider how one would choose the optimum time to construct such a road. The goal is to select the time of construction for which the present value of net benefits passes through a maximum. It is a straightforward procedure to calculate the present value of benefits for different years of construction and then to select the one with the highest value. However, there is an intuitive approach that gives some insights into the problem.

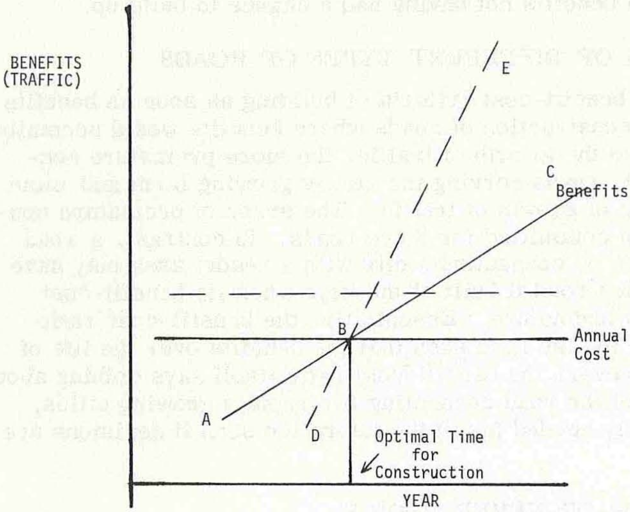
The fact that benefits are increasing while costs remain constant shows that the economic justification for the project is constantly improving. Thus, if the project is justified for construction in any one year, it will be even more worthwhile in future years.

The decision reduces to whether the project should be constructed now or should be postponed till a future year. (Remember that all projects being considered have already been found to have benefits that exceed their costs.) It is not necessary to decide now at exactly what future year the project will be worth constructing.

The saving from postponing construction for one year is the interest on the construction cost of the road plus the maintenance expense for one year. The benefits lost by postponing construction for one year are those for the first year. To decide whether road construction should be postponed, all that is necessary is to compare the first year benefits with the savings in costs. (If benefits are growing, it will often happen that the discounted present value of benefits exceeds one, but the project should not be built yet. Since traffic and benefits increase over time for virtually all roads, a policy of building a road as soon as it has a benefit-cost ratio in excess of one leads to premature construction.)

The foregoing situation is shown in Figure 1. The horizontal line is the annual cost of the project interest, amortization, and maintenance. By assumption it does not vary with when the project is constructed. The line AC represents the benefits as a function of time. (They probably rise at least as rapidly as traffic.) The optimal time for project completion is B, when the annual benefits are equal to the annual costs.

Figure 1.



It should be noted that projections of future traffic are required only for design purposes and to be sure that at time B the present value of benefits exceeds the present value of costs. Because of the rising traffic levels on most highways, there will be little doubt about project justification by time B. (The time for which the benefit-cost ratio was exactly one will occur before time B.) Thus information on future traffic is less important than it is under the traditional benefit-cost criteria. The need for projections of future traffic for design puposes still remains, of course.

Notice that there is an interaction of growth of traffic and the optimum time of construction through the design and cost of the road. If a road has a high rate of traffic growth, the design traffic load will probably raise the cost of construction and postpone the optimum time of construction. In Figure 1 the dotted horizontal line represents the cost of a road built to higher standards to handle a higher level of traffic. It can be seen that the optimum time of construction is later for the road on the fast-growing route than for the road along the slow-growing route. What is happening is that a higher level of traffic is needed to justify the more expensive road than is needed for the less expensive road.

DEVELOPMENT PERIODS

The case discussed in the foregoing was one in which the benefits and amount of traffic varied only with calendar time, not with the date of construction of the highway. This is probably an accurate description of the situation for many highway improvement projects, especially the smaller ones that do not cause enough of an improvement in travel time to generate much traffic or produce changes in the location of industry. However, there are new roads for which the traffic in any given year depends on when the road was built. For instance, a new road may lead to the construction of new factories along it. Traffic to and from these factories would use the road, thus raising the benefits. Hence, the 1980 benefits from a road might be greater if it had been constructed in 1970 than if it had been built in 1975. This is because factories locating in the area between 1970 and 1975 would have located so as to make maximum use of the road.

This situation is easily handled. The present value of benefits from constructing the road now are computed. Likewise the present value (as of now) of benefits is computed for construction one year from now. The difference in the two present-value figures represents the loss of benefits from postponing construction by one year. It includes

not only the loss of the first year's benefits but also the discounted value of the decrease in benefits in each future year from benefits not having had a chance to build up.

EFFECTS ON TIMING OF DIFFERENT TYPES OF ROADS

It was shown that the traditional benefit-cost criteria of building as soon as benefits exceeded costs leads to premature construction of roads where benefits would normally increase over time. The more rapid the growth of traffic, the more premature construction is likely to be. In general, roads serving the slowly growing farm and mine populations will have the lowest rate of growth of traffic. The error of premature construction is least likely to have been committed for these roads. In contrast, a road connecting two rapidly growing cities or connecting a city with a resort area may have a very rapid growth of traffic. Such a road if built at the time when its benefit-cost ratio first becomes one will be very premature. Essentially, the benefit-cost ratio indicates that there is a future need for the road such that the benefits over the life of the road will exceed the costs. However, the benefit-cost ratio itself says nothing about when this need exists. In the case of the road connecting two rapidly growing cities, one may build a road that is definitely needed far in the future too soon if decisions are based on the benefit-cost ratio.

THE NOW-OR-NEVER CHOICE

A benefit-cost ratio provides an indication of whether a road should be built now or never. However, it is seldom that one is faced with a now-or-never decision on a new road. Postponement of construction is usually a realistic option. Where one often gets the now-or-never option is in the design of a road and the selection of specific improvements to be included. For instance, the decision to eliminate a curve or to construct an overpass for a road that is already under construction may be of the now-or-never type. If these are not built during the initial construction it may be impractical to come back and do it later. For planning decisions of this type, the correct rule is to build the project if the present value of added benefits exceeds the present value of added costs. This is so even though the annual costs may prove to be more than annual benefits for the early years of the life of the project.

CHANGES IN CONSTRUCTION COSTS OVER TIME

The discussion so far has assumed that construction costs do not change over time. In practice they do for many reasons, such as residential construction on the right-of-way. Costs of delay include not only the loss of benefits but also any escalation in costs that are expected. For instance, if the cost of constructing a road is estimated to be $1,000,000 today but will be $1,100,000 next year because of construction of a subdivision on the right-of-way, a year's delay will increase costs by $100,000. If costs were expected to decrease (perhaps due to technological progress), the cost of delay would be negative. Likewise, if delay is expected to change the present value of maintenance costs (such as by increasing the length of the road), the change in the present value of all future maintenance represents the cost of delay.

In considering changes in the cost of construction with time, changes due solely to inflation should be excluded unless such changes are also included in the estimates of benefits. It is customary to estimate both benefits and costs assuming a constant price level. Probably the most important cause of increased construction prices is construction of buildings along the right-of-way that must be demolished for the highway. Increased prices for land purchases might also be considered as increased cost for the highway. However, from an economic viewpoint the real cost of using land for a highway is the opportunity foregone to use the land for another purpose. Land values represent the capitalized value of the returns from such foregone uses. Hence, increases in land values usually represent real increases in the annual costs of using land for highways, not just a one-shot increase in costs. However, if highway planners wish to include the savings in the right-of-way costs for land purchases in their programming,

the way to do it is to include the avoidance of price increases as one of the benefits of early construction.

A real benefit of early construction will often be the reduction of relocation expenses and severance damages. Although not included in the financial costs of highways, the social savings from construction of a highway before development of surrounding land should be included as a benefit of early construction. There are a number of such social benefits. One is avoiding the disruption that occurs from putting a highway through an established community. Indeed, if development has not yet occurred, expressways may even serve to provide desirable boundaries between neighborhoods. Patterns of friendship, church and school attendance, and locations of stores will adapt to the highway rather than being disrupted by it. Although most of these costs are nonfinancial, it should be noted that more overpasses are likely to be required to permit continuation of established patterns of community life if the highway is built after community development rather than before. Likewise, with early road construction (or at least announcement of the route), tributary road systems may be laid out so as to connect efficiently with the new highway, saving the cost of reconstructing these routes later and reducing costs for future road users. Likewise, large employers, shopping centers, apartments, and places of amusement can be located so as to utilize efficiently the new highway. This is likely to minimize the total cost of construction for feeder roads and will also reduce travel times because of the smaller distances being driven on slow local roads.

Finally, environmental problems are likely to be reduced if the highway is built before the surrounding land is fully developed. Developers, knowing that houses adjacent to the expressway will be hard to sell, may refrain from building right next to it as long as suitable land is available. Thus a thin buffer zone of undeveloped land may develop along a new expressway. If adjacent land is developed, it is more likely to become commercial, industrial, or apartments than single-family residential. Such uses are less affected by the proximity of a highway, partially because of a smaller area of windows. If development does occur adjacent to an already existing highway, the design is likely to be such as to minimize adverse effects, using techniques such as suitable location on the lot, placing the short end of a building perpendicular to the highway, placing rooms with a small window area (such as garages) adjacent to the highway, minimizing areas of windows on the noisy side of the building (especially if a view of the highway is not considered aesthetic), and installation of storm windows and central air-conditioning. Such design techniques can greatly reduce the adverse effect of a highway on a residential structure but are difficult to apply if the building was put up before the highway.

Finally, people differ greatly in the extent to which they are annoyed by highway sounds and views. If development occurs after highway construction, those who are extremely sensitive to such factors can avoid buying property adjacent to the highway. If the highway is constructed through an established neighborhood, those exposed to the disadvantages will be a representative selection of the population, including some who will be very much bothered by the highway. Some people are likely to move who would not have had to move if they had been able to take the highway into account when they chose their original location.

Thus there are a number of nonmarket benefits from early construction of a road that should be included in the analysis of the optimum time of construction. When added to the cost savings, early construction of roads in developing areas (or at least advance purchase of right-of-way) will often be found to deserve high priority. These factors are not included in traditional benefit-cost ratios or internal rates of return.

MULTI-STAGE PROJECTS

Reference was made to advance acquisition of right-of-way as one technique for avoiding development on the right-of-way. This is just one example of staged construction. It is possible to determine whether stage construction is economical or not by trying different combinations of timings for the construction of different stages and selecting the one for which the present value of benefits minus costs is greatest. If this shows staged construction to be desirable, the optimal timing for the first stage

can be determined by the methods described earlier. For instance, for advance acquisition of right-of-way, the major loss from postponing the expenditure is the increase in the economic cost of the land.

Once the first stage of the project has been executed, the second stage is included as an additional project and the analysis repeated. Because the first project has already been completed its cost is excluded from the costs of the second stage. For instance, where the second stage is to actually build the road on an already acquired right-of-way, the benefits from construction are primarily the first-year benefits to the users (and perhaps greater benefits in future years), and the costs are the annual costs of maintenance for one year and the interest on the construction costs (but not right-of-way acquisition costs) for one year. The cost savings from earlier acquisition of right-of-way are not included.

THE RISK OF PREMATURE CONSTRUCTION

Benefit-cost ratios are very sensitive to the level of benefits in future years. A project may become uneconomic if benefits do not grow as rapidly as projected. This is often used as an argument either for using a cutoff benefit-cost ratio higher than one or for building a risk factor into the interest rate. However, the risk of constructing a road that should not have been built is less using the timing criteria than using the benefit-cost criteria.

Risks can be divided into two categories. One comes from misestimating the rate of growth of traffic and benefits. The other comes from errors in estimating the level of first-year traffic and the resulting level of benefits. The first type of error is likely to be most important for improvements to an existing road where the current traffic provides a good guide to the traffic after completion of the project. However, where a new road is being constructed, errors in the forecast of initial-year traffic are likely.

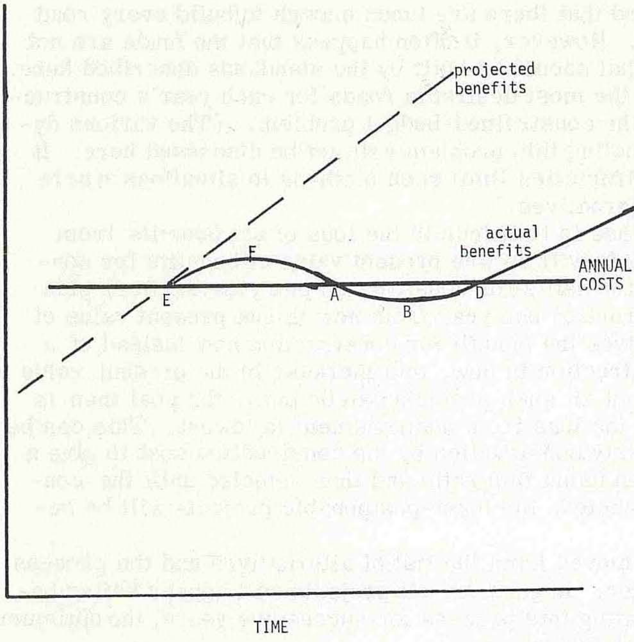
For an improvement to an existing road that is not expected to change the level of traffic, the chance of making a serious mistake in timing is small. To show this, let us return to the case of a project with benefits that do not vary with how long it has been since a project was constructed and construction costs that do not vary with time (to permit graphing). Figure 2 indicates how first-year benefits vary with costs.

For the road construction to have been an error, it is necessary that the benefits in future years drop below the annual cost and that the discounted value of the area under the annual cost line bounded by ABD exceed the value for the area over it bounded by EFA.

Errors in the estimation of the rate of growth of traffic do not cause errors in project timing as long as traffic and benefits increase over time. Because population and per capita travel usually increase, there is relatively little risk of error, and certainly much less than is inherent in the traditional test of whether the benefit-cost ratio exceeds unity. Because construction often must be begun a year or two before the desired date of completion, it is necessary to make a short-run forecast of traffic growth. There is a small risk that this short-run forecast will be in error. Of course, if the design of the road varies with the estimated traffic, errors in prediction will still have the effect of reducing expected net benefits below net benefits with the expected traffic. Even here the widespread use of rules of thumb and prescribed standards for highway design means that the highway design is often little influenced by moderate errors in prediction. In essence, for the typical highway improvement project the element of risk is much less than would be expected from the sensitivity of the benefit-cost ratio to errors in the growth rate for traffic.

The other type of error arises from mistakes in forecasting the initial year's traffic. This is most likely for entirely new roads. With growing traffic, the effect of an error in forecasting the initial year's traffic is merely that the project is built prematurely. The loss from premature construction is that the benefits for the first few years are less than the annual costs of the road. For instance, consider a road with benefits growing at 5 percent per year. Suppose that the only cost was $1,000,000 for construction with an interest rate of 5 percent. Thus the savings from postponement of construction are $50,000 per year. The initial estimates of first-year benefits had been $50,000

Figure 2.



per year. Instead they were only $40,000 because the amount of diversion from other routes had been overestimated. However, the 5 percent straight-line growth rate (based on population growth) is correct. The calculation of the loss from what turned out to be premature construction is as follows:

Year	Benefits	Present Value Factor	Present Value
1	40,000	1.00	40
2	42,500	1.05	40.476
3	45,000	1.1025	40.816
4	47,500	1.150625	41.081
5	50,000	1.21551	
			162.373

The present value of benefits gained for the 4 years of premature operation (at 5 percent) is $162,400. The construction cost of $1,000,000 was incurred 4 years early. The present value of the delayed construction is $ 822,700. Thus, early construction raised the present value of construction costs by $177,300. Because this increase in construction costs exceeds the value of the benefits by $14,900, the road construction was premature. However, it should be noted that a 20 percent error in the estimate of initial-year benefits produced a loss of only 1.5 percent of the project cost as a result of premature construction. This is in spite of the fact that the error reduced the benefit-cost ratio by 20 percent. The actual cost of forecasting errors is much less than is suggested by the sensitivity of the benefit-cost ratio to errors in the initial-year estimates.

It should be noticed that the loss from a wrong forecast would be 20 percent of the construction cost if growth of benefits did not eventually justify the road. This illustrates how growth of traffic serves to reduce the risk in many highway investments. In general, the higher the growth rate of benefits, the lower the risk.

THE LIMITED BUDGET CASE

The discussion so far has assumed that there are funds enough to build every road at the optimal time for construction. However, it often happens that the funds are not adequate to construct all the roads that should be built by the standards described here. It then becomes necessary to select the most desirable roads for each year's construction. This is what economists call the constrained-budget problem. [The various dynamic programming methods for handling this problem will not be discussed here. It should be noted that computational difficulties limit such methods to situations where there are only a small number of alternatives.]

The procedure for handling this case is to calculate the loss of net benefits from postponing a project by one year. This will be (the present value of benefits for construction now minus present value of benefits for construction one year earlier) plus (the present value of costs for construction one year from now minus present value of costs for construction now). This gives the benefit for construction now instead of a year later. If the ideal time of construction is now, this increase in the present value of new benefits will be positive. If not all such projects can be built, the goal then is to postpone those projects for which the loss from postponement is lowest. This can be done by dividing the benefits from early construction by the construction cost to give a priority ratio. If projects are ranked using this ratio and then selected until the construction budget for that year is exhausted, the least-postponable projects will be selected.

The selected projects are then removed from the list of alternatives and the process is repeated for a period one year later. In general, all projects will appear better because of increased traffic. By repeating this process for successive years, the optimum construction budget can be derived for future years.

LIMITATIONS OF THE METHOD

The foregoing method of solution applies only to the case where priority ratios decline over time. This indicates that some progress is being made toward reducing the backlog. This is the situation with the current highway program. However, if an extremely sharp decrease in highway funding was expected, this condition might not be met. Then one might want to build a project now that would not be needed until some time in the future because the funds would not be available to build it in the future. When this happens, the relevant choice is no longer between construction now and construction one year in the future, which was the assumption on which this discussion was built.

DISCLAIMER

The views presented here are the author's and do not necessarily reflect the views of the U.S. Department of Transportation.

REFERENCES

1. Hirshleifer, J., DeHaven, J. C., and Milliman, J. W. Water Supply, Economics, Technology, and Policy. Univ. of Chicago Press, 1960, pp. 169-174.
2. Road User Benefit Analysis for Highway Improvements. American Association of State Highway Officials, 1960.
3. Winfrey, Robley. Economic Analysis for Highways. International Textbook Co., Scranton, Pa., 1969.
4. Margolin, S. A. Public Investment Criteria. M.I.T. Press, Cambridge, 1968, pp. 74-79.
5. Margolin, S. A. Approaches to Dynamic Investment Planning. North Holland Publishing Co., Amsterdam, 1963.
6. Arrow, K. Optimal Capital Policy, the Cost of Capital, and Myopic Decision Rules. Annals Inst. of Statistical Mathematics, Vol. 16, No. 1-2, 1964, pp. 21-30.
7. Beenhakker, H. L. The Optimal Year for Starting a Transportation Project. Revista Brasileira de Transportes, jul./set. 1966, Suplemento No. 1.
8. Hejal, S. S. An Economic Priority Model for Rural Highway Improvements. Purdue University Joint Highway Research Project, Rept. 28, 1970.

SPECIFICATION OF PLAN-MAKING PROCEDURES FOR A GIVEN PLANNING SITUATION

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Earlier papers by the authors identified requirements and characteristics of an operational metropolitan plan-making process. This paper proposes a method for designing plan-making procedures for use in such a process. The first part of the paper specifies a simple iterative process involving planners and decision-makers and examines possible approaches for its elaboration. The role of optimizing and predictive models is discussed, and it is concluded that a predictive approach is preferred. Parallel, series, and cascade-type dialogues for the plan-making process are then examined. Procedures for designing a plan-making process for a given planning situation are examined in the second part of the paper. Four types of information concerning participants, constraints, relationships, and preferences are specified and applied in designing procedures. Each type of information can be expressed as a flow chart; the compatibility of these flow charts determines whether the plan-making process is practicable and to what extent an iterative process is needed to prepare and evaluate alternative plans. If iterations can be avoided in the planners' procedures, then the entire process is shown to be more efficient. A short example based on land use and transportation planning concludes the paper.

•OUR RESEARCH on the specification or design of plan-making procedures began with a review and analysis of experience with the preparation and evaluation of alternative metropolitan land use and transportation plans. The findings and documented analysis were published in 1970 as "Metropolitan Plan Making" (1). In one section of that monograph we recommended a cyclic, learning approach to plan preparation, evaluation, and decision-making. Decision-makers were advised to view the plan-making process as an opportunity to learn what alternatives exist, what their consequences are, and what objectives are served by these alternatives. Because a learning process implies a question-and-answer type of dialogue, the cyclic or iterative nature of this process is central to its success. The desirability of completing several cycles of the plan preparation-evaluation-choice sequence was evident in the planning programs reviewed.

In this paper, some further research results on the design of planning procedures are presented. Our more detailed findings have been published as "An Interim Report on Procedures for Continuing Metropolitan Planning" (2). This report consists of two major parts. The first concerns the design of plan-making procedures for a given situation, the subject of this paper. The second part proposes procedures for a continuing or ongoing planning process. The distinction is as much in the approaches taken to the problem as in the problems themselves.

In this paper and in two earlier publications (3, 4) the principal findings on procedures for a given planning situation are reported. Two additional papers (5, 6) present some of the principal results on procedures for continuing planning. These

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results are at present being tested and refined; subsequent reports and papers will document the outcome of this effort.

Our purpose in this paper is to present some findings on the definition and design of plan-making procedures for a given planning situation or problem. By plan-making procedures we mean the tasks and activities in which planners and decision-makers engage in order to produce a set of decisions concerning future actions and policies, which we call a plan. These procedures require time to execute; the implementation of a set of procedures over time is called a plan-making process. These plan-making procedures utilize models, methods, and techniques to produce required analyses, predictions, and evaluations. In part, then, the design of plan-making procedures is the problem of specifying how planners apply available methods and techniques, or invent new ones, in order to engage in problem-solving.

These procedures also assume the existence of an organizational and institutional framework for plan-making. Important questions, such as who are the decision-makers, whom do they represent, and what are their responsibilities, are largely assumed away here in order to focus on the question of what decision-makers do. However, as noted in the following, the institutional and organizational framework does place important constraints on planning procedures.

This paper is presented in two main parts. The first part defines an iterative plan-making process involving planners and decision-makers. Four general procedures are defined: search; prediction; evaluation; and choice and direction of further search. Several types of iterative processes are examined using this framework.

The second part of the paper takes up the problem of designing detailed plan-making procedures in response to a specific situation or problem. A classification is proposed for the types of information available for designing these procedures, and a method for organizing and analyzing this information is described.

An inherent difficulty of treating such a complex subject as the design of plan-making procedures in a short paper is that the result inevitably appears too superficial, general, and abstract to be useful to planning agencies. With this difficulty in mind, we attempt only to interpret our major findings here, and we urge the reader to pursue the technical details in the publications and reports cited. Our explicit objective throughout this research is to address operational problems of plan-making as found in metropolitan planning agencies. If we can stimulate these agencies, themselves, to be more concerned with the design of their own plan-making process, perhaps we have achieved some measure of success.

DEFINITION OF AN ITERATIVE PLAN-MAKING PROCESS

In a general sense, a plan-making process may be characterized as a dialogue or formal discourse among several parties concerning desired values of the performance characteristics of a system. By a performance characteristic, we mean any characteristic (function or combination of variables), say C(x), of the system being planned and the performance, say P(x'), of that characteristic in some specific context. The following types of performance characteristics have proved useful in our research:

1. Empirical—C(x) <u>does</u> have P(x');
2. Projected—C(x) <u>would</u> have P(x');
3. Hypothetical—C(x) <u>could</u> have P(x')
4. Preference—C(x) <u>should</u> have P(x'); and
5. Political—C(x) <u>will</u> have P(x').

Thus the statement, "The peak-hour freeway operating speed is 25 mph", is an empirical performance characteristic. Operating speed is the characteristic; 25 mph is the performance value. The verb <u>is</u> denotes an observed value; alternately, the verb should be denotes a desired value. A more definitive treatment of these concepts is given elsewhere (<u>2</u>, <u>4</u>, <u>5</u>).

Our view is that plan-making is a dialogue about the performance characteristics of a system, in particular preference and political-type statements. The plan produced by this process is a record of these statements, together with all the supporting analysis

and documentation. This record can reflect the situation at a point in time, or it can be a dynamic, continuing record of the dialogue. Languages for conducting this planning dialogue over time are one of the principal products of our research (5, 6) but are not described in detail here.

In the general case, this dialogue involves two groups:

1. Decision-makers—designated by the government as defined by the prevailing institutional, legal, and organizational framework; and
2. Planners—the group of technically qualified professionals retained by decision-makers on behalf of the government.

Clearly, the decision-makers may include representatives of various groups and interests, or they may choose to involve such groups in the plan-making process. The planners may include professionals of all types; our problem is to specify how these two groups interact in conducting the plan-making dialogue.

The simplest specification of the roles of planners and decision-makers is shown as Figure 1. Planners produce alternative plans consisting of (a) proposed actions for the government or public sector and (b) proposed policies concerning the actions of the private sector. Decision-makers exercise choices concerning various aspects of the alternative plans on behalf of their constituents and direct the search for new alternatives. In terms of the performance characteristic concept, alternative plans consist of alternative sets of performance values and their consequences. Making choices on alternative plans means reaching agreement over time on a specific value for each performance characteristic, subject to the values of other related characteristics. Note that these choices need not be made all at once but may be made over a considerable time period as either conditional or final decisions.

Optimization Versus Prediction

The next step in detailing the definition of the plan-making process is to expand the relationship between planner and decision-maker of Figure 1. Suppose that the decision-makers agree to consider some specific development problem. We wish to determine how they should proceed in general and how they specify plan-making procedures for the particular problem at hand. We assume there is a context for this problem, both in terms of previous efforts to deal with it and in terms of related problem areas. To fix ideas, we consider the problem to be preparation of a transportation system plan in the context of regional land use and watershed planning.

Our strategy in further detailing the plan-making dialogue is to explore the difficulties posed by the question, "How should the process begin?" In terms of Figure 1, how can planners propose actions and policies without direction from decision-makers? How can decision-makers give direction without some information on what actions are feasible? While it should be understood that no attempt to break this cycle can be totally successful, alternative approaches to the problem can lead to very different results.

Broadly speaking, two idealized approaches to this dilemma have been proposed—the optimizing approach and the predictive approach. The optimizing approach begins the dialogue between planners and decision-makers by assuming that a definitive statement of goals, objectives, and preferences is given by the decision-makers. The planners then search for an optimum action according to this statement, taking into account the consequence of each action. Various mathematical programming models and search procedures have been devised in attempts to implement this approach. One of the best examples in land use and transportation planning is the plan design model research of the Southeastern Wisconsin Regional Planning Commission (7, 8).

In contrast, the predictive approach begins the dialogue with a set of proposals by the planners. These proposed actions and policies may be in response to the planners' perception of society's goals, or they may include proposals for alternative sets of goals. In either case, the decision-makers exercise choices and formulate directions for further search based on their reactions to the proposals.

Of course, in practice both approaches are much more flexible. Both require several rounds of dialogue for the completion of satisfactory plans. In the optimizing case, these rounds are sometimes referred to as sensitivity analysis, meaning that

incremental changes in variables and constants are made to determine the effect on the optimum solution. In the predictive approach, additional rounds constitute further searching of the action space. In this sense the distinction between the two approaches may be regarded as slight; however, given some additional considerations, the differences become sharper.

Without developing all the details here, we believe there are strong reasons for preferring the predictive approach. Our principal objection to the optimizing approach is that the information required, operational objectives, is precisely what is not known in planning. Plan-making procedures need to be structured to help decision-makers discover what their objectives are for the system. Moreover, any system plan involves many objectives, some of which are in conflict; the plan-making process is the mechanism for negotiating agreements over these conflicts. For these and several technical reasons having to do with optimizing models themselves, we believe it is not realistic at this time to structure the entire process in terms of optimizing models.

In contrast to the optimizing approach, it seems preferable to present a rich predictive picture and to allow the decision-makers gradually to form and express their preferences from these alternative pictures by adding alternatives and modifying them in the course of the dialogue. This mutual learning process is more flexible in resolving conflicting elements and obtaining concrete expressions of the decision-makers' preferences. This, in brief, is the predictive approach.

Search, Prediction, Evaluation

In expanding the concept of the predictive approach, consider the following three-part definition of the planners' role:

1. Search—specification of a course of action;
2. Prediction—conditional statements about the future; and
3. Evaluation—analyses of a course of action and its predicted consequences useful in resolving conflicts and providing a basis for choice.

These three procedures are shown in Figure 2 and discussed in the following.

Search is the least understood procedure of the plan-making process as far as formal methods are concerned. Architectural design is an example of an intuitive approach to the search problem, but it is not well developed as a formal process. Search may be defined initially as a discrete combinatorial problem. In so doing, all possible actions are defined; an alternative plan is one particular combination of such actions. In contrast, the optimizing approach identifies the optimum combination given an objective function.

The overriding questions of the search procedure concern how alternatives are to be selected from all possible combinations. This is a kind of optimal sampling problem; the more information that is available from the decision-makers, the more useful the sample will be to them. Key questions to be answered in drawing this sample are

1. How many alternatives should be prepared?
2. How different should the alternatives be?
3. At what level of detail should alternatives be prepared?

Heuristic methods may be useful for searching the combinatorial space for alternatives with properties requested by the decision-makers. In the second part of the paper, we examine some procedures for simplifying this search process.

Prediction assumes a modeling capability for making conditional statements about the future. The applicability of a given predictive model to a planning situation depends on the acceptance of several assumptions concerning the behavior of individuals, private organizations, and public institutions. These assumptions have a number of implications as follows:

1. Does the specification of the model result in stable model parameters?
2. What is the effect of the proposed course of actions on model stability; are the model inputs outside the range of the data on which the model was calibrated?

3. What changes are occurring outside the system being modeled that might affect the predictions?

Clearly, predictive models are most valid when the immediate future is the time period of interest, and the actions considered are quite similar to the present. Just how immediate and how similar are matters of ongoing discussion among model-builders and their clients? The procedures described in the second part of the paper incorporate the behavioral statements of models and help to clarify whether a model's assumptions are violated.

Evaluation in the predictive approach to plan-making takes on a somewhat specialized meaning. Since we have assumed that the plan objectives are at best only partially known, we maintain that it is not possible for the planners to develop single, comprehensive measures of each alternative, such as preference rank orderings. Although the planners may develop formal evaluation systems for assisting decision-makers in overall rankings, we suspect the synthetic abilities of decision-makers are far superior to any existing method of this type. Moreover, the concept of overall rankings conflicts with our assumption that decisions are made incrementally at the level of specific performance characteristics, conditional upon consideration of further alternatives designed to explore the implications of these decisions.

In this view of evaluation, we focus attention on two problems. The first problem concerns the resolution of conflicts among decision-makers and among performance characteristics. Evaluation supports the bargaining and conflict resolution procedure through supplying and interpreting needed information about alternatives. Although conventional procedures such as benefit-cost analysis may provide useful information to the decision-makers' bargaining process, many other types of information are also required.

The second problem of evaluation is improving the basis of choice. As search and predictive methods improve, the basis of choice for the decision-maker improves, but it also widens and becomes more cumbersome. The planners can assist here by presenting summary, as well as detailed, performance characteristics, thereby synthesizing the rich predictive picture of the future. This procedure may involve value judgments by the planner, and these need to be made explicit. In the predictive approach, then, some of the difficulties of the basis of choice are shifted to the problems of search and prediction.

Iterative Nature of the Predictive Approach

Using the search-prediction-evaluation framework expounded in the foregoing as the definition of the planners' role in plan-making, we can now consider more explicitly the iterative nature of dialogues between planner and decision-maker. Consider the following situation, which is probably the simplest possible case. The planners are asked to prepare two initial alternatives; they choose arbitrarily two sets of proposed actions. They enter the variables corresponding to each set of actions in a predictive model and obtain two sets of predictions for the alternatives. Then, they describe and summarize these results on a number of measures thought to be useful to the decision-makers.

One alternative may be outside the range of validity of the predictive model; for instance, the output may contradict the assumption that the parameters remain stable. Also, the decision-makers will probably not choose right away between the two alternatives but may suggest modifications to each or ask for a combination of the two alternatives. In any event, the planners need to reexamine their work following the first round of discussions with the decision-makers, as shown by the feedback arrow in Figure 2.

The iterative character of this process is necessary in order to consider conflicts, as already described. It is also important in the event the first alternatives are not very satisfactory, and to consider improvements if suggested. Finally, it is essential in case it is agreed that the alternatives cause the predictive model to operate outside its range of validity. In such a case, one would have to choose actions for the next round that are more likely to remain within range; this generally means alternatives

closer to the existing situation. In case the decision-makers feel this would entail solutions that are even less satisfactory, one might conclude that the model is not appropriate; its range of validity being too small, it should be replaced by another model. The decision-makers might also conclude that they must lower their expectations.

These advantages are associated with the iterative character of the method. However, such iterations are time-consuming, and one would like to restrict them as much as possible. Accordingly, at the outset of the process one would like to be able to present alternatives that are as satisfactory as possible and that at least satisfy all the known constraints on the actions. In the second part, procedures yielding only such alternatives will be defined.

However, as seen above, in some cases iterations are essential. One would like in these cases to require that the planners redo as little of their work as possible; to achieve such a result, one might attempt to decompose the dialogue between planners and decision-makers into several different dialogues. One possibility, illustrated as Figure 3, is decomposition into independent, or parallel, dialogues. Then, if an alternative for Part I of the system is not satisfactory, a new iteration is not required for Part II. This decomposition is only possible if (a) the two parts of the system do not interact, (b) there are no joint constraints on the proposed actions of Parts I and II, and (c) the decision-makers are not interested in the relationship of Parts I and II.

A second possibility is decomposition into sequential, or serial, dialogues as shown in Figure 4. Here, Part I might refer to the main features of the system, while Part II refers to the details. A choice among major alternatives could then be made before the alternatives for the detailed system are designed and evaluated. The design for Part II would only take place once the choice of the design for Part I had been made.

If two systems are interdependent and therefore cannot be planned in a sequential manner, then a multisystem dialogue is necessary. A cascade-type multisystem dialogue is shown in Figure 5. This situation might apply when a single set of models does not provide for predictions of the consequences of each of the systems being planned. An example is planning for land use and transportation (Part I) and water, sewer, and flood control (Part II). If a single model is avialable for both systems, then the single-system situation described above would apply. The rationale for such integrated models is precisely to avoid the difficulties encountered in the multisystem case, for these difficulties can only be solved at the cost of additional iterations.

Suppose two systems are planned independently, as in the case of decomposition of a single system dialogue into independent dialogues. An alternative is presented for each system, within the range of validity of the model, and also perfectly satisfactory to the decision-makers. Iterations might still be needed for the following reasons:

1. The two alternatives are not compatible. For instance, their costs exceed the available budget. This is a symptom that a joint constraint on the action spaces of the two systems was neglected.

2. The alternative of one system violates the range of validity of the other system's predictive model. This is a symptom that interactions between the two systems were neglected.

3. The overall alternative, obtained by combining the alternatives for each system, is highly unsatisfactory. Indeed, the two systems might combine in a highly undesirable fashion; by modifying each system, one might achieve a more desirable overall alternative. This is a symptom that decision-makers are sensitive to the way the two systems relate and that this aspect was neglected.

Similar difficulties arise if the two systems are planned sequentially, except that difficulties of the first type would not occur. Under certain conditions, however, one should be able to design various systems independently or sequentially, evaluate them independently or sequentially, and decompose the dialogue or several dialogues into independent parts or sequential parts. As one can recognize, this can greatly simplify the plan-making procedures and reduce the dimension of the search for alternatives. We now turn to methods for designing such procedures.

DESIGNING THE PLAN-MAKING PROCEDURES

The iterative plan-making process defined in the foregoing is likely to be a time-consuming and somewhat cumbersome operation, even for planning a single system. If applied to a complex of systems, any attempt to be comprehensive is very likely to be unworkable unless steps can be taken to eliminate or reduce redundant or unnecessary activities. In this part, we explore the basis for procedures that are efficient in this sense and suggest ways in which such procedures can be designed for a given planning situation. The concepts underlying these proposed procedures are quite straightforward. Their objective can be thought of as designing procedures that minimize unnecessary processing of information by decision-makers and planners, but guarantee that

1. The alternatives presented to the decision-makers are feasible, in the sense that the actions specified to be taken are implementable; and
2. Every alternative that is feasible can be obtained by such a procedure.

The types of interactions and interrelationships examined here as a basis for designing these efficient planning procedures are as follows:

1. Real-world interactions among various elements of the system being planned and in particular between decision-makers' actions and the effects of those actions;
2. Legal, institutional, and fiscal frameworks within which plan-making takes place and in particular the constraints these factors place on actions or policies available to decision-makers;
3. Capabilities and competencies of planning groups in various public agencies and the communication networks linking them; and
4. Structure of preferences of decision-makers that can be expressed more or less independently of the problem at hand.

Designing efficient plan-making procedures involves some knowledge about the real-world interactions among the elements of the system being planned. This knowledge is assumed to be given in the form of a model or a system of models that specifies the predicted outcome for each action under the control of the decision-makers. However, decision-makers cannot choose actions arbitrarily, as they are limited by feasibility constraints such as legal requirements, budget limits, or regulations. The set of acceptable actions and their predicted outcomes, then, defines the set of feasible alternatives.

Next, information about the expertise and capability of each of the groups employed in the plan-making process can be used to facilitate its design. For example, a planning group for a particular system, such as transportation, requires inputs from other groups and provides output to still others. These kinds of interdependencies among group capabilities and their associated communications networks are basic information for the design of the plan-making process.

Finally, some knowledge about the decision-makers' preference structure is also required. This knowledge may be in the form of priorities about the various parts of the system, or it may take the form of indifference statements by decision-makers on the relationship of some parts of the system. However, what is not required in this approach is information about decision-makers' preferences, themselves. (The difference between preferences and preference structures is discussed later.) As the amount of this type of knowledge increases, the cumbersomeness of the plan-making process can be decreased through more use of independent and sequential dialogues.

In summary, the a priori information requirements for the design of predictive plan-making procedures are relatively light, as compared with the information requirements of the optimizing approach to plan-making. This in itself is important, for this a priori information is to be taken as given in the design of plan-making procedures and therefore must be agreed on by the decision-makers.

Using Flow Charts to Design Procedures

The four types of interrelationships described suggest a method for designing more efficient procedures. A method is needed to identify (a) precedence relationships among

Figure 1. A simple iterative plan-making process.

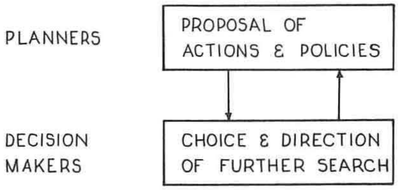


Figure 2. Predictive plan-making process for a single system.

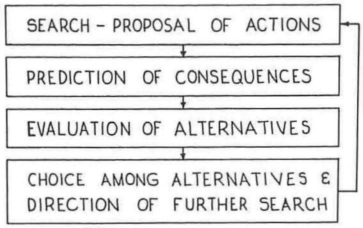


Figure 3. Plan-making process for independent dialogues.

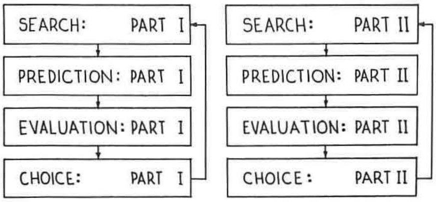


Figure 4. Plan-making process for sequential dialogues.

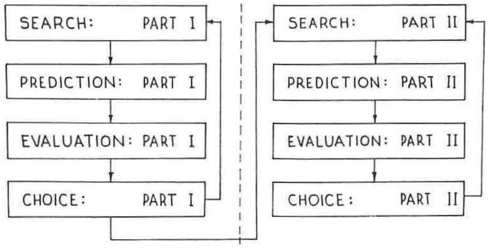


Figure 5. Plan-making process for a multisystem dialogue.

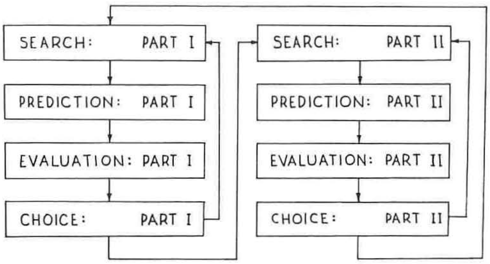


Figure 6. Flow chart illustrating concept of directed circuits.

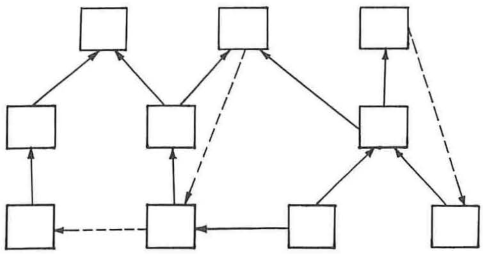


Figure 7. Planning group capabilities flow chart.

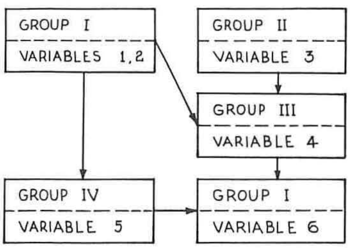


Figure 8. Flow chart guaranteeing feasibility with control variable subsets.

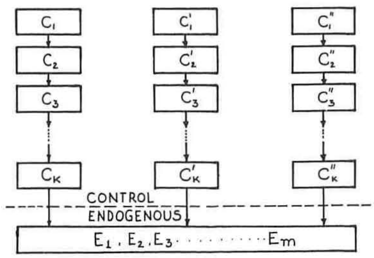


Figure 9. Flow chart of structure of decision-maker preferences.

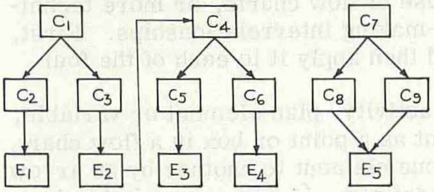


Figure 10. Planning group capabilities flow chart.

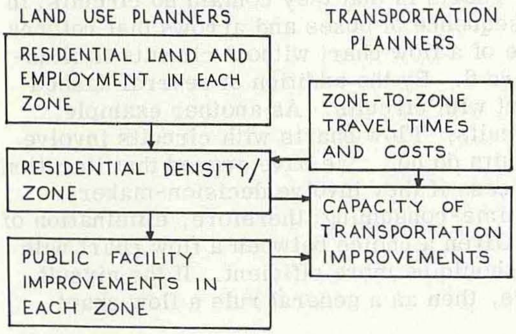
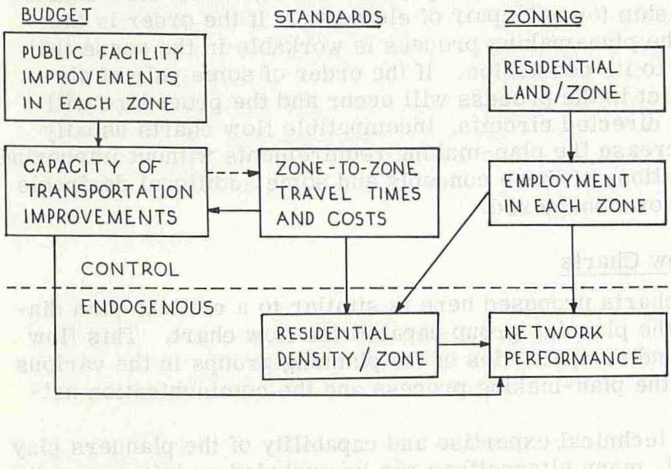


Figure 11. Flow chart guaranteeing feasibility.



plan-making elements and activities and (b) conflicts among these precedence relationships. The method for achieving this result is a natural extension of the critical path diagram or PERT chart (9). We now explore the use of flow charts, or more technically directed graphs, to display and analyze plan-making interrelationships. First, we examine the use of this approach in general and then apply it to each of the four types of interrelationships outlined above.

Consider that we may represent a plan-making activity, plan element or variable, requirement or constraint, or preference statement as a point or box in a flow chart. Moreover, we may represent a relationship from one element to another by an arrow; note that only directed, or one-way, relations are defined. (A two-way relation is represented by two arrows, one in each direction.) A flow chart (graph) consists of boxes (vertices) and arrows (arcs) and is a very general and useful device for displaying various types of information needed for designing plan-making procedures.

An important characteristic of some flow charts is that they contain no circuits; in such flow charts it is not possible to find a sequence of boxes and arrows that returns to the first box in the sequence. An example of a flow chart without circuits is illustrated by the boxes and solid arrows in Figure 6. By the addition of several dashed arrows, Figure 6 is converted to a flow chart with circuits. As another example, Figures 1 through 5 are flow charts with circuits. Flow charts with circuits involve iterations, whereas flow charts without circuits do not. We have argued that iterations are a desirable feature of a plan-making process if they involve decision-makers. However, iterations are also expensive and time-consuming; therefore, elimination of circuits may conserve planning resources. Given a choice between a flow chart with circuits and one without circuits, the latter should be more efficient. If the circuit does not include inputs from decision-makers, then as a general rule a flow chart without circuits is preferred.

Flow charts, then, are a method for organizing interrelations among planning elements and analyzing their efficiency. Because there are several types of interrelationships, there may be several flow charts involving the same variables in different ways. We wish to determine if these flow charts are compatible; that is, do the flow charts specify the same order relationship for each pair of elements? If the order is the same in each flow chart, then the plan-making process is workable in the sense that each flow chart can be followed to its conclusion. If the order of some pair of elements is reversed, then a conflict in the process will occur and the procedure will need to be redesigned. As with directed circuits, incompatible flow charts usually result in iterations that may increase the plan-making requirements without improving the effectiveness. Some applications of these concepts and some additional desirable properties of the approach are now considered.

Planning Group Capabilities Flow Charts

Inasmuch as one of the flow charts proposed here is similar to a critical-path diagram, we begin by considering the planning group capabilities flow chart. This flow chart portrays the capabilities and competencies of the planning groups in the various public agencies participating in the plan-making process and the communication network linking them.

In any plan-making process, technical expertise and capability of the planners play a critical role. On the one hand, many alternatives can be excluded as inferior on the basis of technical considerations, and much can be done to obtain optimal solutions to small-scale problems. Therefore, the planners' technical capabilities represent a source of efficiency in plan-making. On the other hand, these same technical groups may incorporate the inertia of an institution, for example, when confronted with new models or techniques. This problem of inertia is particularly serious in an area of technical expertise undergoing rapid expansion and improvement. Some individuals may become, or feel they have become, obsolete; their roles may need to be redefined to permit them to contribute to the process. Our objective is to develop methods for analyzing such situations in order that technical expertise can be properly matched to modeling capabilities.

The planners are usually divided into several groups, each being in charge of an area of the proposal within its special technical competence. Clearly, these groups cannot work without coordination, because the absence of coordination generally results in infeasible, uncoordinated alternatives. Moreover, some groups require information from others in order to design a proposal for their area of responsibility. However, coordination is costly in terms of money and especially in terms of time, because some groups have to wait for the work of others to be completed in order to start their own.

To analyze this problem, represent (a) by boxes the various tasks that each group performs and (b) by arrows the requirement that some tasks cannot be executed before certain others. Each task consists of a group determining the alternative values for a specified set of variables. The manner in which these values are determined depends on whether the task is a search, prediction, or evaluation type of procedure. Flow charts designating such tasks and their relationships are termed planning group capabilities flow charts; Figure 7 shows a simple example. A desirable restriction to place on the construction of this type of flow chart is that it not contain any directed circuits; this means no task is required to be performed both before and after some other task or set of tasks. If this is not possible, then iterations are required, thereby increasing the complexity and cost of the process.

Flow Charts Guaranteeing Feasibility

A planning group capabilities flow chart guarantees that the groups involved are able to prepare proposed values for the policy variables. But this does not guarantee that the proposal is feasible. What should be the flow of information between various planning groups in order to guarantee that the proposals obtained are feasible? Clearly, the answer to this question is contained in the various constraints placed on the actions and policies proposed in the plan. These constraints may be classified into two types:

1. Real-world interactions among the various elements of the system being planned, including both physical and behavioral relationships; and
2. Legal, institutional, and fiscal constraints defined by the governmental framework in which plan-making takes place.

A major element of the plan-making process is prediction of the consequences of each action under the control of the decision-makers. The knowledge for making this prediction is given in the form of a model or system of models. The inputs to these models include (a) values for the control or policy variables, determined in the search procedure with directions from the decision-makers, and (b) assumptions and data. The output or endogenous variables of the model are not subject to direct decision-maker intervention but must be indirectly manipulated through changing the values of the control variables.

Moreover, decision-makers cannot specify arbitrary values for control variables because they are limited by feasibility constraints such as legal requirements, budget constraints, or regulations, some of which may be imposed by a higher authority. These relationships may be conveniently represented in a single flow chart called the flow chart guaranteeing feasibility. We now consider a procedure for specifying the control variable portion of such flow charts.

Suppose that there are two sets of control variables, C and C′, and two planning groups or agencies, the first in charge of C and the second in charge of C′. Now suppose a constraint on these control variables involves some variables from the set C and others from the set C′. The work of the first group must then be coordinated with the second group to guarantee the feasibility of the proposal. Two procedures can be followed that will guarantee feasibility: Group one prepares a proposal for its variables in C, and then group two chooses values for its variables in C′ such that the combined proposal is feasible; or conversely, group two could specify its variables first, followed by group one. Such a procedure could be illustrated by a very simple flow chart with a box designating each group's variables and an arrow designating the order in which the groups propose values for their variables. Clearly, any flow chart

with an arrow between group one and group two guarantees the feasibility of the proposal. Hence, there is a class of flow charts representing design procedures that guarantee the feasibility of proposals; because one would not like to present infeasible proposals to decision-makers, it is desirable that a procedure belonging to this class of flow charts be used.

At the same time, it is important that a procedure from the class of planning group capabilities flow charts be used. Therefore, it is highly desirable to determine whether among all possible procedures for designing proposals th[illegible]s one that belongs to both classes of flow charts. Such a flow chart always doe[illegible]ist. Indeed, all linear flow charts belong to the class guaranteeing feasibility; such flow charts consist of a linear sequence of boxes connected by arrows, all in the same direction. Linear flow charts always guarantee feasibility of proposals because decisions are made sequentially rather than independently. Among all possible linear arrangements of variables, there must exist at least one that is compatible with the planning group capabilities flow chart.

However, linear flow charts involve major inconveniences; they specify a procedure that is lengthy and requires a large amount of information transmission. Therefore, it is desirable to try to identify subsets of control variables that are independent from each other with respect to every constraint. These subsets can then be designed independently without violating any constraints.

Several of these concepts are shown in Figure 8; linear sequences of control variables are shown as C, C', and C''. Each of these subsets corresponds to a feasibility constraint; the arrangement of variables shown is one possible order of designing these subproposals that guarantees feasibility. These subproposals form the inputs to a model determining the value of several endogenous variables in the set E, which specify the consequences of the proposal.

Flow Charts of Structure of Decision-Maker Preferences

We now consider the last type of flow chart, which displays the preference structure of the decision-makers. This flow chart is another basis for partitioning the dialogue into independent or sequential dialogues, thereby greatly reducing the amount of information that needs to be processed at any one time.

The concept of preference structure can perhaps be best introduced by means of an example. Suppose that decision-makers take up the problem of making a plan for schools, hospitals, and other related public facilities. Upon discussion of these facilities they agree that it is important to locate such facilities in their proper relationship to households; however, they are not concerned with how schools and hospitals are located with respect to each other. Given agreement on this point, plan-making for schools and hospitals can proceed in an independent, parallel manner because the decision-makers' preferences are structured independently for these two plan elements. Note that it has not been assumed that the decision-makers agree on how schools and hospitals should be located, but only on the lack of relationship between the two types of facilities.

More generally, decision-makers' preferences for a given alternative plan are given by their individual utility functions for the values of the control and endogenous variables in that plan. If, upon discussion, it is agreed that the utility function for several variables can be partitioned into several partial functions, then the planning effort can be similarly partitioned. This information can also be displayed as a flow chart; an example is shown in Figure 9. The example shows that control variables C_7, C_8, and C_9 and endogenous variable E_5 can be considered independently of the others; moreover, consideration of C_4, C_5, C_6, E_3, and E_4 can be delayed until agreement is reached on C_1, C_3, and E_2.

The information contained in flow charts of this class is also useful in revising alternatives. It shows, from the decision-makers' viewpoint, what variables are affected by a change in a given control variable. For example, suppose the decision-makers are not satisfied with the value of E_4. The situation might be improved by changing only C_6. This leaves unchanged the decision-makers' level of satisfaction about all features except C_6 and E_4.

Compatibility of Flow Charts

We may now confront the flow chart of preference structure with (a) the planning group capabilities flow chart and (b) the flow chart guaranteeing feasibility. In order to find a desirable procedure for designing alternative plans, one tries to find three flow charts, one from each class, that are compatible; compatibility is achieved if the order of the boxes in one flow chart does not contradict the order specified by each of the other flow charts.

As discussed earlier, it is always possible to find flow charts of the first two types that are compatible by using linear flow charts. The flow chart of preference structure may provide additional information for the task of specifying the order of variables in such a linear flow chart. As was shown in Figure 9, it may be possible to avoid certain plan revisions if the third type of flow chart is available.

One may ask at this point whether it is always possible to find three compatible flow charts. The answer is that there always exists a compatible, but trivial, flow chart belonging to the three classes, namely the flow chart with all variables in one box. Accordingly, the design of plan-making procedures can also be viewed as the disaggregation of this trivial case. It may be that any non-trivial flow chart of preference structures is incompatible with any flow chart guaranteeing feasibility. This situation implies a loss of flexibility in the process of reshaping alternatives. However, this flexibility can be recouped by considering, for example, a plan-making process that requires iterations to ensure plan feasibility.

As a final example, consider the question of compatibility of two flow charts, shown as Figures 10 and 11, for land use and transportation planning. Figure 10 shows the information flow between land use planners and transportation planners. Figure 11 shows in solid arrows a flow chart displaying budget, standards, and zoning constraints as control variables with residential density and network performance as endogenous variables whose values are predicted by a land use and transportation model, given the values of the control variables.

Examination of the order relations of the variables in these two flow charts indicates they are compatible, which permits us to conclude that

1. The plan-making procedure is workable in that it does not assign to any planning group a task outside its competence, as specified in Figure 10; and
2. Any proposal prepared by this procedure will be feasible in the sense of satisfying the constraints depicted in Figure 11.

Now consider a modification of Figure 11 by replacing the arrow from travel times and costs to transportation capacity by the dashed arrow in the opposite direction. This implies that the standard on travel times and costs is dropped and that capacity limitations determine these variables. As a result of this change, Figure 11 is now incompatible with Figure 10, since travel times are needed by transportation planners to determine capacity in Figure 10. This situation, which is quite realistic, suggests that an iterative procedure is needed to determine not only capacity but also residential density and public facilities. This is true because it is now necessary to introduce an arrow from capacity back to travel times into Figure 10, thereby creating two directed circuits. Because these circuits add to the planners' work load and do not benefit decision-makers, they should be eliminated if possible.

TESTING AND APPLICATION

The findings described are largely conceptual at this stage. They are supported in our detailed report (2), together with a rigorous mathematical appendix (10) that includes some algorithms constructing compatible flow charts. We recognized some time ago that further development of these concepts should be in the direction of testing and applications. Research in progress, which is drawing on the experience of the Southeastern Wisconsin Regional Planning Commission, is providing useful information for testing and refining these procedures. By testing, we mean (a) observation of an actual plan-making process to obtain detailed procedural requirements and related information and (b) construction and analysis for flow charts of the observed process.

This should permit new insights and conclusions on the validity of the approach. Although our current studies in Southeastern Wisconsin are mainly directed toward the testing of languages for continuing planning (5, 6), the information obtained should be useful as well for testing the procedures set forth here.

Another area for further investigation concerns the role and structure of predictive models in the plan-making process. Predictive models are incorporated into our procedures in the flow chart guaranteeing feasibility. For this purpose, control and endogenous variables need to be identified. An examination of operational land use and transportation models suggests that the question of control variables has not been fully explored by model-builders. Without developing the details here, it appears that the basic structure of land use and transportation models will permit the definition of alternative sets of control variables, depending on the purpose at hand. Additional research on the structure of these models is being planned in order to define and explore alternate model specifications suitable for differing plan-making situations.

ACKNOWLEDGMENT

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REFERENCES

1. Boyce, D. E., Day, N. D., and McDonald, C. Metropolitan Plan Making. Monograph Series No. 4, Regional Science Research Institute, Philadelphia, 1970.
2. Boyce, D. E., McDonald, C., and Farhi, A. An Interim Report on Procedures for Continuing Metropolitan Planning. Regional Science Dept., Univ. of Pennsylvania, Philadelphia, 1971.
3. Boyce, D. E. The Metropolitan Plan Making Process: Its Theory and Practical Complexities. In Urban and Regional Planning: London Papers in Regional Sciences, (Wilson, A. G., ed.), Vol. 2, Pion Ltd., London, 1971, pp. 96-109.
4. Boyce, D. E. Toward a Framework for Defining and Applying Urban Indicators in Plan Making. Urban Affairs Quarterly, Vol. 6, No. 2, 1970, pp. 145-171.
5. McDonald, C., and Boyce, D. E. Tabular Form as a Language for the Planner. Paper presented at 54th Annual Conference of the American Institute of Planners, San Francisco, Oct. 1971.
6. McDonald, C., and Boyce, D. E. Prototypical Forms of Dialogue for Metropolitan Planning. Paper presented at 40th National Meeting of the Operations Research Society of America, Anaheim, Calif., Oct. 1971.
7. Southeastern Wisconsin Regional Planning Commission. A Land Use Plan Design Model, Volume One: Model Development. Waukesha, Wisc., 1968.
8. Southeastern Wisconsin Regional Planning Commission. A Land Use Plan Design Model, Volume Two: Model Test. Waukesha, Wisc., 1969.
9. Creighton, R. L. PERTing a Transportation Study. Highway Research Record 38, 1963, pp. 55-77.
10. Farhi, A. Constructing Procedures for the Design of Alternatives, Appendix A of D. E. Boyce et al., An Interim Report on Procedures for Continuing Metropolitan Planning, Univ. of Pennsylvania, Philadelphia, 1971.

A METHODOLOGY FOR COMPUTATION OF THE ENVIRONMENTAL CAPACITY OF ROADWAY NETWORKS

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In evaluating alternative transportation systems for the Urban Corridor Demonstration Program in Louisville, Kentucky, it became necessary to develop a procedure that would directly correlate the transportation system with the environment through which it passes. This methodology was necessary because all roadway and transit improvements could only be made to surface streets; no freeway facility directly serves this area. Changes in traffic on surface streets directly affect the environment of those people living, working, or shopping adjacent to the facility. These environmental effects must be quantified in order to properly evaluate the transportation improvements. A methodology was developed whereby street segments were stratified based on roadway and land use characteristics. People residing, working, or shopping adjacent to these street "prototypes" were questioned in such a way as to develop an annoyance index for each prototype. This annoyance index related people's perceptions of noise, air pollution, and safety to the level of traffic on the street. Through previous questionnaires the environmental criteria of noise, air pollution, and safety were found to be most significant when related to traffic. Similar street prototypes with various levels of traffic were studied, and relationships between annoyance and traffic volume were then developed for each prototype. From these relationships, an "environmental capacity" expressed in vehicles per day was established for each roadway segment in the study area. These results were used to evaluate the effect on the environment of various transportation improvements considered.

• THE CONCEPT of environmental capacities was developed as one part of the transportation planning process utilized on an Urban Corridor Demonstration Project for an area within the City of Louisville, Kentucky. In developing a viable transportation system for Louisville's South Corridor area, it became evident that only surface street facilities were available to serve the 144,000 people residing in this area. Because only surface facilities were available for improvement, the problem of the environmental effect of increased traffic had to take into account the consequences of alternate strategies on the entire corridor.

To deal with the complex relationship between the environmental aspects of a community and its transportation network, it was necessary to develop a quantifiable systematic technique of relating automobile networks with adjacent land uses. The criteria chosen to define this relationship were noise, air pollution, and pedestrian safety. After identifying all combinations of road types and land use types, classes or prototypes were established. Interviews were then conducted to ascertain if correlations could be obtained between people's annoyance concerning the three criteria and the characteristics of the traffic on the road. Success was obtained in enough cases to allow the

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generalization of the results to the entire corridor study area and all streets and activities within it. Thus, the traffic improvements recommended for implementation not only accounted for a set of specific environmental impacts but were supported by them. It was, therefore, possible to deduce the total number of people that would be annoyed over the aspects tested, if given a description of their environment and the ADT on their street.

THE CONCEPT OF ENVIRONMENTAL CAPACITIES

Environmental capacities are based on the idea that there is a relationship between transportation systems and the natural, man-made, and social environment. The environment the transportation system passes through and serves must be related to that transportation system in common terms. The methodology relating transportation to the environment must be capable of articulating and evaluating alternative solutions that not only represent the best, safest, and most convenient means of moving people but also represent a compatible total environment.

The environment does not have an infinite ability to accept transportation systems. The endeavor outlined here attempts to view people's annoyance with specific environmental criteria as having quantifiable limitations and also attempts to show that the attributes of transportation systems are related to this annoyance and that this relationship can be quantified.

The term "environmental capacities" was chosen purposefully as a name analogous to the term "capacities" as now used by transportation planners, defined (1) as follows:

> The maximum number of vehicles which has a reasonable expectation of passing over a given section of a lane or a roadway. . . during a given time period under prevailing roadway and traffic conditions. . . . The capacity would not normally be exceeded without changing one or more of the conditions that prevail. In expressing capacity, it is essential to state the prevailing roadway and traffic conditions under which the capacity is applicable.

The major characteristics of concern in defining a roadway's capacity involve the physical characteristics, design, and control of the roadway itself and the nature of traffic on the roadway.

Environmental capacities can best be described through a definition that reads as follows: "The maximum number of vehicles that should be permitted to pass through a given environmental situation over time and under prevailing environmental conditions. The capacity should not normally be exceeded without changing one or more conditions that prevail. In expressing capacities, it is essential to state the prevailing environmental conditions under which the capacity is applicable and the criteria utilized to establish them."

OVERVIEW OF THE CONCEPT

There are two ways of looking at the environment:

1. Examine it as an artifact in a detached systematic fashion (its distribution of activity types, distribution of structures, geology, accident rates, crime rates, ambient noise levels, family incomes, topography, the attributes of traffic passing through it, etc.); and
2. A perceptual evaluation of environment by the people living and working in it and/or passing through it ("it's noisy," "uncomfortable," "a nice place to live," etc.).

These two approaches are obviously interrelated, yet the method of articulating and evaluating them is quite different.

The essence of the process of establishing environmental capacities involves the specification of the first environmental definition and relating characteristics under the second environmental definition to it in a systematic fashion for transportation-related phenomena. As an example, it is technically feasible to ascertain and describe the traffic volumes and types in various areas of Louisville's South Corridor, but the essential information for setting a standard is a perceived quality and the establishment of acceptability of different traffic volumes as a function of perceived attributes.

This process becomes more complicated when it is realized that many variables are involved as an individual evaluates his perception of his environment or various aspects of it.

It is apparent that one would find wide variation between individuals concerning any perceived environmental criteria, given a particular environment and transportation situation. Many imponderables present themselves. If, for example, people in a community are proud and happy with their area, they will be inclined to pass over a particular environmental problem. If recreational facilities are scarce in a given area, then the street may represent a real problem for child safety. But the magnitude of the problem cannot be compared to other similar situations unless we can determine the adequacy of recreational facilities in all communities studied.

People who rent or see their stay as short-term are less concerned with many issues than people who own or are long-term residents. The age of the individual may concern him with different priorities. Income, family size, the degree to which he lives outdoors, his background and previous experiences, all may mitigate against consistent attitudes about similar or even identical phenomena.

Of equal importance are difficulties in quantification of the physical phenomena themselves. The criteria on which environmental capacities can be related to people's annoyance levels are as follows:

1. Sight,
2. Smell,
3. Pressure,
4. Sound,
5. Taste,
6. Pedestrian safety,
7. Conflicts and desired movement patterns,
8. Disturbance in television and radio reception,
9. Imagined qualities,
10. Dirt and litter, and
11. Damage to vegetation and wildlife.

Through a series of questionnaires, it was found that the criteria that people directly relate to transportation and from which an annoyance level could be ascertained are

1. Noise,
2. Air pollution, and
3. Child safety.

The process utilized to establish which environmental issues (criteria) were most important to the people in the various communities within the South Corridor was begun in an earlier phase as part of the community goals analysis begun November 10, 1970. At that time, 20,000 questionnaires were distributed. Several questions referred to "environmental problems caused by transportation in your community." The results present acceptable evidence that, of all transportation-associated environmental problems, three are mentioned in the substantial majority of cases: noise, air pollution, and child and pedestrian safety.

We must caution at this point that, simply because we received a certain common set of environmental issues, we have no guarantee we will be able to find consistency in the kind and degree of complaints in any given environmental situation.

ENVIRONMENTAL PROTOTYPES

The need existed to test the perceptual response to stimuli in the environment caused by vehicular transportation systems. It was clearly established thus far that questionnaires from inhabitants of the environment were a reliable perceptual response source. The problem now was how to categorize streets and their environments into homogenous units for collection of detailed response data. The relationship between traffic and environmental problems must be measured across like street situations (environments). That is, all aspects of the environment should be alike except the traffic.

The initial step in the establishment of prototypical transportation environments was to divide the vehicular arteries graphically by directional lanes into "street types." Further division resulted from spatial analysis of the artery.

The next step was a stratification based on the functional land use. The street types and land uses were then combined to obtain environmental samples. Those spatial differences that must be considered are more specific in scale than just land use. For example, distance from streets to dwelling units and whether trees were growing between the streets and dwelling units might serve as a basis for breaking down street categories. Photographic studies taken at approximately 7.5 feet above the roadway with a 24-mm lens further clarified this differentiation in environmental attributes.

Essentially, the "prototype" is the classification of environmental attributes of a street. Questionnaires were distributed to people residing, working, or shopping adjacent to each prototype. After evaluating the questionnaires, it became necessary to develop an even finer breakdown of prototypes because of mixed land use and demographic data.

APPROACH UTILIZED IN ASCERTAINING ENVIRONMENTAL CAPACITIES

The actual physical entity (transportation) and people's perception of that entity's environmental attributes (noise, pollution, safety) are confounded by many uncontrolled variables that involve differences in the observers, the contexts within which observations are made, and the variability of the entity itself.

Our approach to this problem has consisted of a rigorous attempt to isolate environmental prototypes (street categories) in terms of their main attributes and then attempt to plot responses concerning noise, air pollution, and pedestrian safety as a function of traffic characteristics (ADT and percentage of trucks and buses) over environmental prototypes with similar attributes. We would then test the degree to which responses concerning the established transportation-related environmental criteria vary as a function of transportation characteristics across similar environmental situations and contexts.

If acceptable correlations are achieved, it is then possible to set limitations on the traffic, based on the degree of acceptable nuisance within a given environmental situation (prototype).

METHOD TO ESTABLISH CAPACITIES

The method utilized and described herein approaches this problem by initially dividing responses to particular criteria and testing for correlations with traffic characteristics stratified by environmental contexts. Environmental capacities are calculated for each criterion and then assembled in chart form for each prototype, allowing examination of variation between criteria. This is important because it does yield an indication of which characteristics of the transportation system are the most disrupting to the environment through which it passes and to what degree this might be alleviated by particular actions.

A Response Scale

Based on the nature of the responses to a second round of environmental interviews, three questions proved the most useful. All other questions received answers which could be interpreted in varying ways, yielding a low consistency for scaling. The following three questions were utilized:

6. How would you describe the noise caused by traffic on your street?
   Quiet____ Acceptable____ Bothersome____ Bad____ Terrible____
9. How would you describe the air pollution caused by traffic on your street?
   Not noticeable____ Acceptable____ Bothersome____ Bad____ Terrible____
13. How much of a problem does the traffic on your street represent to you (or your family) as pedestrians? (If business, use "or your customers")
   No problem____ Acceptable____ Bothersome____ Bad____ Terrible____

The questions were initially set up so that each response represented our subjective estimates of equal jumps in perception and the responses were weighted numerically from 0 through 4 in equal steps of 1.0. The mean for each prototype/each question was then calculated and was utilized in testing annoyance (mean/question/prototype) variations as a function of variation of the stimulus index.

A Stimulus Scale

Several descriptions of transportation characteristics are commonly utilized, usually referring to the amount and types of vehicles passing over a given section of roadway over time: average daily travel (ADT); vehicles per hour; percent trucks; percent buses; and peak-hour volume. Of these, the only measure available across all the established prototypes was average daily travel. Where data were available for other descriptions, they were utilized only as a means of identification and elimination of particular cases that failed to respond to the norm for ADT.

In each attempt at correlating the respondent annoyance index as a function of the transportation characteristic index for each of the stratifications, the following check was made: The validity of r_s (regression coefficient for sample data) from the samples as an estimate of r_p (regression coefficient for actual population) for the population, with the null hypothesis $p = 0$, was tested at significance level 0.05 using the Fisher and Yates statistical tables for critical r values published by Freund (2). Any correlation that did not pass this test was discarded. A sample curve developed by this method is shown in Figure 1.

Computation of Capacity

The method was used to compute the environmental capacity for all prototypes. For each prototype an acceptable response curve resulted from at least one environmental criterion (noise, air pollution, public safety). If more than one criterion yielded an acceptable curve, the environmental capacity was chosen as the lowest figure; e.g., noise may have yielded a capacity of 10,000 VPD whereas public safety may have yielded a capacity of 5,000 VPD for the same prototype, and therefore the capacity of this street segment would be set at 5,000 VPD. Because the street prototypes were chosen so as to represent all major roadways within the corridor, a "capacity" could then be established for all major roadways in the study area. A sample of the resulting environmental capacities and the existing ADT is given in Table 1.

ANALYSIS

With "environmental capacities" established for all streets in the study area, the effect on the environment of each recommendation could be established. Each improvement will change the street prototype (e.g., two lane to four lane) or traffic volume or both. These changes can be analyzed as to their effect on the environment by comparing the predicted traffic on the street segment with the environmental capacity of that prototype.

Total systems can be compared by establishing the number of miles of roadway above environmental capacity. The street segments now over environmental capacity are shown in Figure 2. The segments that would be over environmental capacity in 1975 with no roadway or transit improvements (Fig. 3), with roadway improvements only (Fig. 4), and with both roadway and transit improvements (Fig. 5) were compared to ascertain the effect of the proposed transportation system on the environment of Louisville's South Corridor.

This analysis tool proved to be an extremely useful vehicle for assuring the best transportation system for the environment while still allowing the flexibility of considering several alternatives at low cost. Although this work is only a beginning step and only applicable to Louisville's South Corridor, it is felt that this same concept and methodology could and should be used whenever transportation system improvements are being considered.

Figure 1. Annoyance at noise versus average daily traffic.

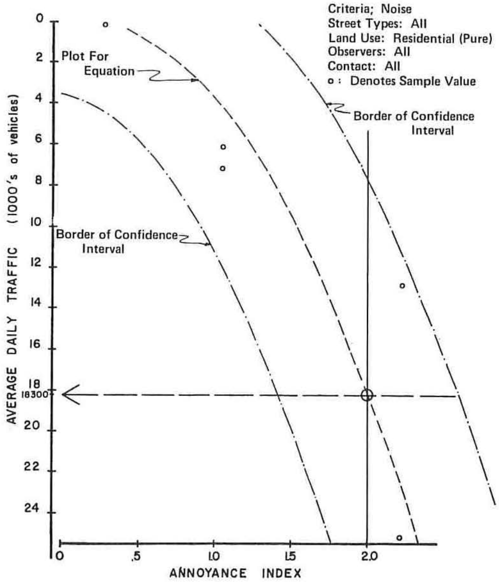


Table 1. Sample of environmental capacities obtained.

Prototype Characteristics	Current Volume (ADT)	Environmental Capacity (ADT)	Controlling Environmental Factor
Commercial and institutional, two lanes each way at grade	7,500	14,100	Air pollution
Commercial, institutional, and industrial mixed, two lanes each way at grade	12,500	35,700	Noise
Commercial, institutional, and residential, two lanes each way at grade	17,500	14,100	Air pollution
Commercial, institutional, and recreational, two lanes each way at grade	25,000	14,100	Air pollution
Commercial and institutional, two lanes each way, some at grade and some elevated	25,000	35,700	Noise
Commercial, institutional, and industrial mixed, two lanes each way, some at grade and some elevated	12,500	35,700	Noise
Commercial and institutional, some streets two lanes each way and some two lanes one way, at grade	12,500	14,100	Air pollution
Commercial, institutional, and industrial, some streets two lanes each way and some two lanes one way, at grade	25,000	14,100	Air pollution
Commercial and institutional, some streets two lanes each way and some three lanes one way, at grade	2,500	35,700	Noise
Commercial, institutional, and industrial, some streets two lanes each way and some three lanes one way, at grade	7,500	35,700	Noise
Commercial, institutional, and residential, some streets two lanes each way and some three lanes one way, at grade	12,500	35,700	Noise
Commercial, institutional, and recreational, some streets two lanes each way and some three lanes one way, at grade	17,500	14,100	Air pollution
Commercial and institutional, some streets two lanes each way and some four lanes one way, at grade	7,500	14,100	Air pollution
Commercial, institutional, and industrial, some streets two lanes each way and some four lanes one way, at grade	12,500	14,100	Air pollution
Commercial, institutional, and residential, some streets two lanes each way and some four lanes one way, at grade	17,500	35,700	Noise
Predominantly residential with some commercial and institutional, the streets two lanes each way at grade	15,000	13,300	Noise
Predominantly residential with some commercial and institutional (60 percent or more residential), with streets two lanes each way at grade	15,000	13,300	Noise
Residential with some industrial, the streets two lanes each way at grade	17,500	13,300	Noise
Residential, some streets two lanes each way at grade and some two lanes each way elevated	17,500	14,100	Noise
Residential with commercial and institutional, some streets two lanes each way and some two lanes one way, at grade	12,500	15,500	Public safety
Residential with industrial, some streets two lanes each way and some two lanes one way, at grade	17,500	15,500	Public safety
Residential with some streets two lanes each way and some two lanes one way, at grade	25,000	15,500	Public safety
Residential with commercial and institutional, some streets two lanes each way and some three lanes one way, at grade	10,000	21,300	Public safety
Residential with industrial, some streets two lanes each way and some three lanes one way, at grade	23,200	21,300	Public safety
Residential with some streets two lanes each way and some three lanes one way, at grade	17,500	19,400	Noise
Residential and recreational, some streets two lanes each way and some three lanes one way, at grade	25,000	21,300	Public safety
Residential with most streets two lanes each way and some four lanes one way, at grade	12,500	19,400	Noise
Residential with commercial and institutional, some streets two lanes each way and some one lane each way, at grade	2,500	14,100	Noise
Residential and industrial with some streets two lanes each way and some one lane each way	7,500	14,100	Noise
Residential with most streets two lanes each way and some one lane each way	25,000	14,100	Noise
Residential with streets two lanes and three lanes each way, at grade	12,500	13,300	Noise
Residential with some commercial and institutional, the streets two lanes each way at grade and three lanes each way elevated	12,500	21,300	Public safety
Residential with industrial, the streets two lanes each way at grade and three lanes each way elevated	17,500	21,300	Public safety

Figure 2. Streets over environmental capacity at time of study.

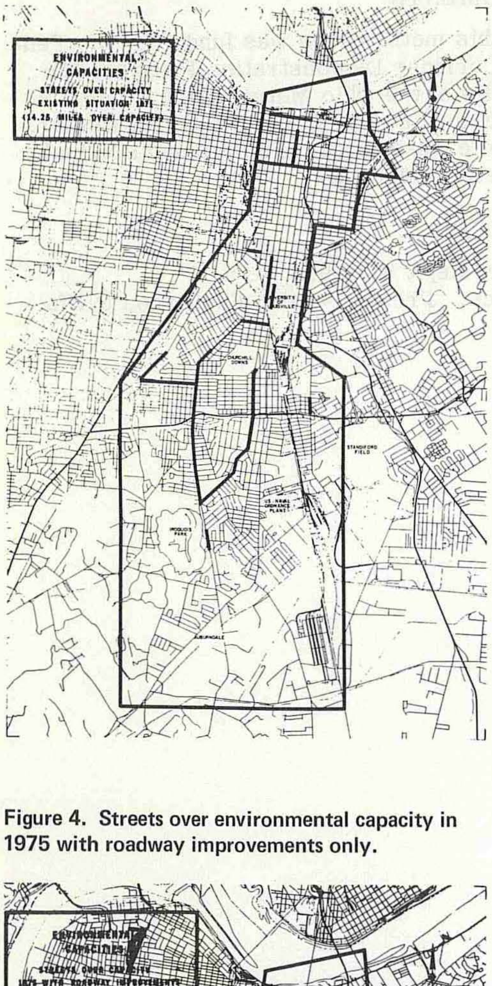


Figure 3. Streets over environmental capacity in 1975 with no improvements.

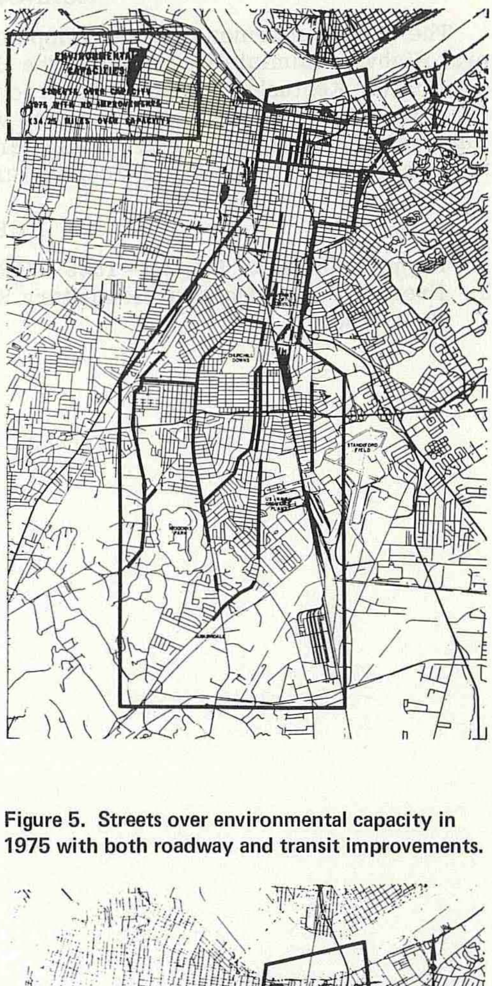


Figure 4. Streets over environmental capacity in 1975 with roadway improvements only.

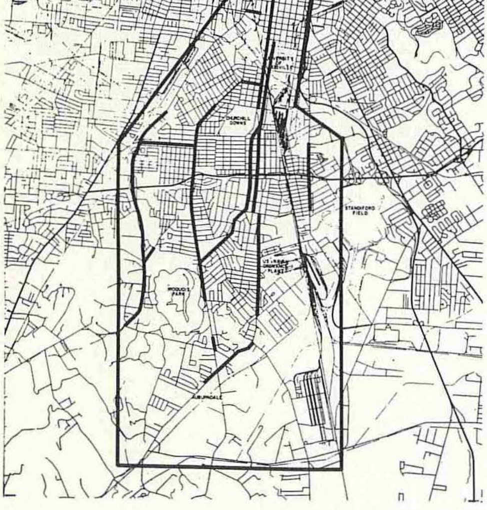
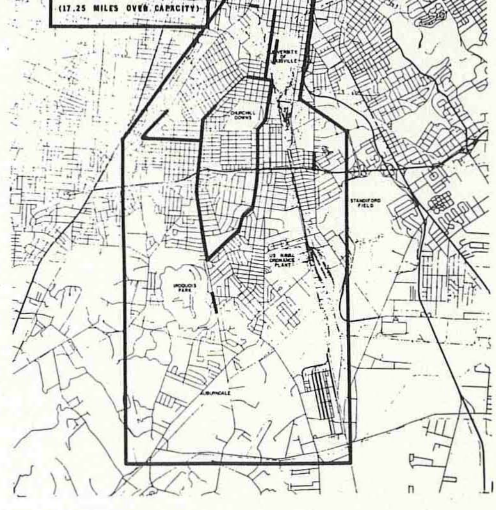


Figure 5. Streets over environmental capacity in 1975 with both roadway and transit improvements.



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REFERENCES

1. Highway Capacity Manual—1965. HRB Spec. Rept. 87, 1965, p. 5.
2. Freund, J. E. Modern Elementary Statistics. Prentice-Hall, Englewood Cliffs, N.J., 1967.

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